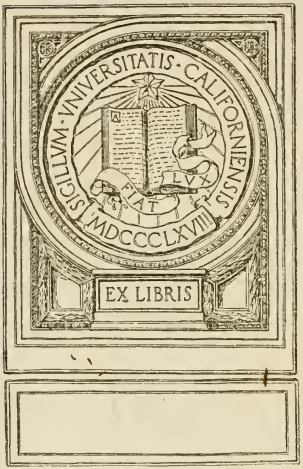
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TREATISE

ON

FORTIFICATION.

OR,

Lectures delivered to Officers reading for the Staff.

BY

CAPTAIN LENDY, F.G.S., F.L.S., &c.

DIRECTOR OF THE PRACTICAL MILITARY COLLEGE OF SUNBURY.

"The use of the spade, pick-axe, and barrow is as essential for the defensive, as that of the musket and bayonet is for the offensive operations of the army."—*Article* 56, *Duties in Camp—Queen's Regulations.*

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DEDICATED

(BY PERMISSION)

TO H. R. H. THE DUKE OF CAMBRIDGE,

ETC. ETC.,

COMMANDER-IN-CHIEF.

UNIVERSITY OF CALIFORNIA

PREFACE.

For a reason difficult to understand, candidates for the Army are not expected to possess any information on this important branch of their future profession. A trifling knowledge of Fortification was demanded of them a few years ago; but, strange to say, one of the first so-called improvements introduced into army education, after the Crimean war, was the entire suppression of this subject. However, the competition for entrance into the Staff College, and the qualifications required of candidates for Staff appointments, have kept up the study of the science among a certain number of officers of the Line.

A small sketch of Fortification was published by me a few weeks before the alteration in the subjects of examination was made, but as it was intended merely to give a general, and therefore superficial, knowledge to young officers, it became necessary to prepare a series of lectures for those who were reading for the Staff.

Having, more especially, the examinations in view, it was essential to avoid speculations and theories not founded on facts, and to compile from such sources only as would be likely to prove practically useful. This I have attempted to do, borrowing from the following sources :—

The Courses in use at Woolwich, Sandhurst, and Chatham; the Professional Papers, the Aide-memoire to Military Sciences; the Mémorial du Génie; the Aide-mémoire d'Artillerie; the excellent works of Zastrow, Baron Maurice, Noizet, Mangin, Choumara, Dufour, Mandar, Jebb, Emy, &c. &c.

To adhere to the elements of the subject, and yet to convey a large amount of instruction in a small compass, has been my endeavour.

Three-fourths of the English Staff have read Fortification with me. This course was compiled for them, it is now printed at their urgent request, and is intended for them and their successors.

A. F. LENDY.

Sunbury, September, 1861.

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ERRATA.

PAGE.

2, *line* 14, *instead of* gomer *read* Gomer.
5, „ 8, „ Millar „ *Millar.*
11, „ 1, „ *Hollow Shot read* (20). *Hollow Shot.*
11, „ 5, „ (1) „ (21).
26, „ 9, „ A sufficient „ (45). A sufficient.
28, „ 7 *from bottom, instead of* 1797 *read* 1697.
45, „ 12, *instead of* nto ten „ into ten.
45, „ 16, „ $\frac{249}{50}$ „ $\frac{240}{50}$.
47, „ 4, „ The diagonal lines being *read* The diagonal lines, being.
52, „ 5, „ find a means *read* find means.
56, „ 5, „ G G „ G G′.
56, „ 11, „ G G „ G G′.
58, „ 3 *from bottom, instead of* G N *read* G H.
67, „ 3, *instead of* H K *read* G K.
73, *instead of* FIG. 123 *read* FIG. 133.
76, *line* 3 *from bottom, instead of* for *read* or.
76, „ 2 „ „ aces „ faces.
101, *last line, instead of* march to follow *read* method to follow
109, *heading* „ EMBRATURES „ EMBRASURES.
111, *last line,* „ ov′ *read* vv′.
111, fig. 223, e e′ omitted.
120, *line* 8, *instead of* connects *read* conceals.
124, „ 14 *from bottom, instead of* 5 deep, *read* 5 feet deep.
140, *instead of* CHAPTER VIII. *read* CHAPTER VII.
142, *line* 11, *instead of* plane of sight, *read* plane of site.
148, „ 11, „ 6 *read* 9.
149, „ 3, „ bends, *read* binds.
157, *instead of* CHAPTER XI. *read* CHAPTER IX.
185, *line* 6 *from bottom, instead of* resorted to. When the enceinte *read* resorted to: when the enceinte.
225, „ 9 *from bottom, instead of* marks *read* masks.
226, „ 3, *instead of* SECTION B. „ SECTION B.
227, „ 4, „ Mons. „ Mons,
233, „ 3, „ hove *read* have.
233, „ 11, „ *Flying Sap* „ *Flying* Sap.
234, „ 9 *from bottom, instead of* 23½ feet „ 2½ feet.
248, „ 11 *from bottom, instead of* advance ports *read* advanced posts.
259, „ 21, *instead of* 1656, *read* 1856.
293, *lines* 4, 3, 2 *from bottom, instead of* towers contained two casemates, or subterranean, &c. &c. *read* towers contained casemates, or subterranean vaults, built bomb-proof; each flank had two casemated guns firing through embrasures 6 feet above the level of the ditch; making, with the two guns mounted on the platform of each tower, altogether eight pieces only for the defence of the ditch.

346, *line* 6 *from bottom. instead of* $\sqrt{\frac{p}{p}}$ *read* $\sqrt{\frac{p}{p'}}$,
387, „ 9 *from bottom, instead of* thread *read* tread.
402, „ 10, *instead of* marked *read* masked.
413 to 436, *heading, instead of* BASTION *read* BASTIONED.
420, *line* 20, „ $\frac{1}{5}^{0}$ *read* $\frac{1}{6}^{0}$
442, „ 24, *instead of* 14 yards *read* 28 yards.
... „ 25, „ 16 „ „ 32 „
... „ 27, „ 30 „ „ 25 „
... „ 28, „ 64 „ „ 56 „
... „ 29, „ 83 „ „ 80 „
443, „ 5, „ , this *read* ; it.
... „ 9, „ dv, *read* dV.
450, „ 4, „ AS *read* as.
... „ 5, „ Ab and B *read* ab and b.
... „ 6, „ A, Ac, Ac′ *read* a, ac, a′c′.
465, „ 2, „ 20 yards *read* 15 yards
466, „ 7, „ O Z = 10 yards *read* O *l* = 10 yards.

A TREATISE

ON

FORTIFICATION.

CHAPTER I.

ARTILLERY.

SECTION I.—Various Kinds of Ordnance.

(1). There are four sorts of ordnance employed in the service: guns, carronades, howitzers, and mortars.

Guns are used to project shot or shells horizontally, or at very low angles.

Carronades are used like guns to throw shot; they are shorter and lighter; but they are almost gone out of use, and are employed only where guns cannot be had.

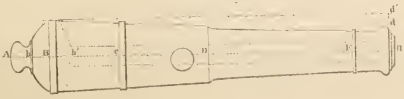
Howitzers are used to project shells at small angles: they have a greater diameter of bore in proportion to their weight.

Mortars are used to project shells at high angles, generally 45°: they are much shorter and thicker.

A piece of ordnance is either of bronze or of cast-iron.

(2). An ordinary gun is divided into five parts: the *cascable*, or portion between the base ring B, and the extremity A; the *first reinforce* from B to C; the *second reinforce* from C to D; the *chase*, or portion between the ring D, and the neck moulding E; the *muzzle* from E to H.

Fig. 1.



The *bore* is the cylindrical cavity through which the shot is discharged: its diameter is called *calibre*.

The *axis* is the imaginary line that joins the centres of the base ring and of the muzzle.

The *dispart* is half the difference $d\,d'$ between the diameter of the base ring and that of the muzzle.

The *breech* is the part $b\,b'$.

The *trunnions* are the projecting arms by which the gun is secured to its carriage: their length and their diameter are each equal to one calibre: their axis is perpendicular to that of the gun, and a little below it.

The *chamber* is a cavity at the bottom of the bore, in which the charge is placed to *increase* its effect. Shell guns, howitzers, and mortars, have chambers. There are two kinds of chambers, the cylindrical for small charges (obsolete), and the conical or gomer for larger ones.

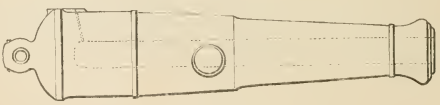
The *windage* is the difference between the diameter of the bore and that of its projectile. It varies in the ordnance from ·025 to ·233 of an inch. It diminishes the effect of the charge, causes injury to the gun by the rebounds of the projectile in the bore, and destroys the accuracy of fire; but it is necessary to make allowance for the foulness of the gun while firing, for the increase of the bulk of the projectiles heated or rusted, or for their irregular shape.

The *preponderance* is the excess of the weight of the part of the gun which is behind above the weight of the part that is before the trunnions. It keeps the gun steady on its carriage, but it should be small to facilitate the working.

(3). Guns are of two kinds: shot guns and shell guns.

Shot guns are distinguished by the weight of their shot; and when there are several of the same kind, they are divided into heavy, medium, and light, or into long and short. There are now in the service two kinds of 68 pounders,

Fig. 2.



Dundas 68-pounder.

two kinds of 56-pounders; three of 42-pounders; thirteen of 32-pounders; six of 24-pounders; five of 18-pounders. There are besides several sorts of 12-pounders, 9-pounders, and 6-pounders. All these guns are of cast-iron, the

Fig. 3.

Monk 32-Pounder.

latter (12-pounders, &c.), obsolete. The brass guns are 12-pounders, 9-pounders, 6-pounders, and 3-pounders.

Fig. 4.

9-Pounder.

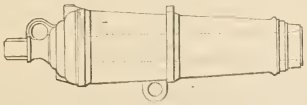
(4). *Shell guns*, introduced in 1824 by General Millar, are distinguished by the diameter of their bore. There are in the service two kinds of 10-inch guns, and four kinds of 8-inch guns—all of them of cast-iron, with gomer chambers.

Fig. 5.

Millar's 8-inch Shell Gun.

(5). *Carronades*, although supplied to the navy, and occasionally found in garrisons, are obsolete. They have no trunnions, and are attached to the carriage by means of a loop under the piece: the muzzle is scooped out. They have a chamber, and are short and light in proportion to their weight. There are carronades 68-pounders, 42-pounders, 32-pounders, 24-pounders, 18-pounders, 12-pounders, 9-pounders, and 6-pounders.

Fig. 6.

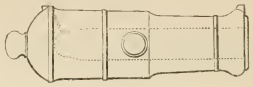


68-Pounder Carronade.

These pieces, introduced in 1779, were found superior to other ordnance on account of their reduced windage; but since then the reduction that has been made in windage of guns has destroyed this superiority.

(6). *Howitzers*, now being superseded by shell guns, whose accuracy and range are greater, are shorter and lighter than guns. They have no dispart, the diameter of the base ring and the swell of the muzzle being equal, or the difference being made up by a patch on the muzzle. The old howitzers had a cylindrical chamber; the new ones, introduced by Millar, are longer, and have a gomer chamber. They are distinguished by the diameter of their shell. There are in the service two kinds of iron howitzers, the 10-inch and 8-inch;

FIG. 7.



Millar 10-Inch Howitzer.

and four kinds of brass ones, the 32-pounder (shell of a diameter equal to the shot of 32-pounder gun); the 24-pounder and 12-pounder of Millar (shells of $5\frac{1}{4}$ and $4\frac{2}{3}$-inch, as the 24-pounder and 12-pounder shots);

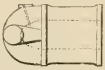
FIG. 8.

24-Pounder Brass Howitzer.

and the $4\frac{2}{3}$-inch howitzer. The last is employed for mountain service with the 3-pounder gun.

(7). *Mortars* are short but thick pieces of ordnance, with gomer chambers: their trunnions are at the extremity of the breech. They are distinguished by the diameter of their shells. There are in the service two kinds of 13-inch, and two of 10-inch mortars, one of each for land and for sea service, and only one kind of

FIG. 9.



10-Inch Mortar.

8-inch mortar. They are made of cast-iron. Besides these, there are two kinds of bronze mortars, the $5\frac{1}{2}$-inch or royal, and the $4\frac{2}{3}$-inch or Cœhorn.

(8). As may be seen, there is no lack of variety in the descriptions of ordnance actually in service, there being, in fact, above 80 different kinds of pieces. The appellation of a piece, especially of a gun, according to the diameter or the weight

of its projectile, is very rarely sufficient to single it out; the distinction of medium, heavy and light, is often made, and the terms short and long also employed. Furthermore, guns are frequently distinguished by their weight and the name of their maker. The different pieces of ordnance may be classed under five heads, viz., those called *ordinary*, which were cast either by Sir W. Congreve or Sir J. Blomefield; those termed "*bored up*" or "*reamed out*," being ordinary guns, which have since 1810 been enlarged in the bore to the next higher calibre; those of General Millar, who began to cast his shell guns in 1824, and to improve on the old guns by making them stronger at the breech; those of Mr. *Monk* (1838), which are thicker at the breech, and lighter in the chase, and whose 32-pounders are often distinguished by the letters A, B, C; those of Colonel *Dundas*, which have a great thickness at the breech, but are not so conical as those of Monk.

SECTION II.—Organization of Artillery.

Artillery is classified into field artillery, including artillery of position; siege artillery; garrison artillery; and artillery for coast defences. The three last named sorts will be treated in a different part of this work (231, 236, 352): we shall, therefore, at present, allude only to Field Artillery.

(9). *Field artillery* is organized into batteries; there are horse A. batteries, field (foot) A. batteries, A. of position batteries, and mountain A. batteries.

Instead of distributing the ordnance into small detachments, as was formerly done, two pieces being assigned to each battalion, it is now customary to attach one or more batteries to each division—generally horse artillery with the cavalry, and field batteries with the infantry. There are, besides, in the reserve, some batteries of horse, field, and position artillery. The number of pieces attached to an army is calculated at the rate of 2 per 1000 men, and on the continent at the rate of 3 per 1000 men.

The force of a battery is generally 6 pieces in England and France, 8 in Russia, Prussia, Austria, &c., 4 in Switzerland. They are either exclusively composed of guns or howitzers, as in Russia and Prussia, or formed of guns and howitzers, as in England, France, &c.

There are in the service two kinds of horse A batteries: one composed of four 9-pounder guns, and two 24-pounder howitzers; another of four 6-pounder guns, and two 12-pounder howitzers. The number of these batteries is one-sixth of that of the field batteries. In France, the proportion is one-seventh; in Russia, one-fourth; in Prussia, three-eighths.

The field batteries consist of four 9-pounder guns, and two 24-pounder howitzers; or of four 6-pounder guns, and two 12-pounder howitzers.

These two kinds of batteries are provided with rockets.

The batteries of position consist of either four 12-pounder brass guns, and two 32-pounder brass howitzers; or of three 18-pounder iron guns, and one 8-inch iron howitzer.

A mountain battery is composed of three 3-pounder guns of $2\frac{1}{4}$ cwt., and one $4\frac{2}{5}$ howitzer of $2\frac{1}{2}$ cwt.

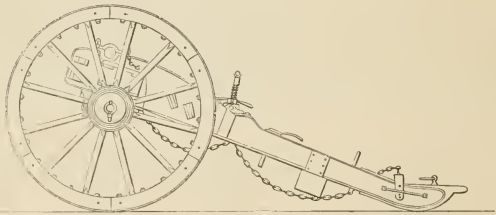
The quantity of ammunition carried into the field by the different guns in the service is, for 18-pounder iron gun, 180 rounds; 32-pounder brass howitzer, 144; or in batteries of howitzers alone, 176; 9-pounder brass gun, 176; 24-pounder brass howitzer, 174; 6-pounder brass gun, 268; 12-pounder brass howitzer, 286.

SECTION III.—Artillery Carriages.

The artillery carriages of the service may be classified into field carriages, carriages for pieces of position, for siege guns, for garrison and coast defence, for transport of heavy ordnance, and naval carriages.

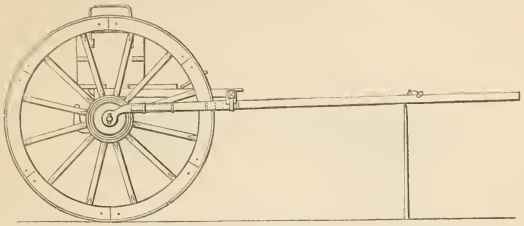
(10). The *Field* gun-carriage varies with the nature of the piece it carries. It is composed of a trail block and two small brackets, one on each side of the trail, and projecting slightly above it. The trunnion holes are cut into these brackets; there is only a pair of them, because the piece occupies the same

Fig. 10.



position in travelling as in firing; and they are placed over the rear of the axle-tree, a disposition which diminishes the strain upon the carriage when firing, and facilitates the limbering up and unlimbering, since it renders the point of the trail lighter. The trail usually inclines at 21°, the inclination tending to check the recoil. The *limber* consists of a frame of wood, placed on wheels, of the same height as those of the gun, and carrying two boxes of ammunition.

Fig. 11.



The trail of the gun-carriage hooks up to a crooked pintail at the back of the limber, and a four-wheel carriage is thus formed fit for travelling.

The gun-carriage is accompanied by an *ammunition wagon:* the body of which carries two moveable boxes and a spare wheel, the limber being the same as that of the gun.

Every battery also contains a *store limber wagon*, a *spare gun-carriage*, a *rocket carriage*, a *store cart*, a *medicine cart*, and a *forge wagon;* all of which, the last excepted, have axle-trees and wheels equal in dimensions to those of the gun-carriages of their battery. There are also two *forage carts* and three *water carts*.

As mountain artillery is generally conveyed on the back of mules, there are carriages only for the guns and howitzers. They are similar to those of the other guns, but have no limber. A pair of shafts for single draught can be attached to the trail, if wanted.

(11). The guns of *position* had formerly a carriage similar to those of siege guns; but a block trail carriage has lately been introduced for the 18-pounder gun, similar to, but heavier than, that for field guns.

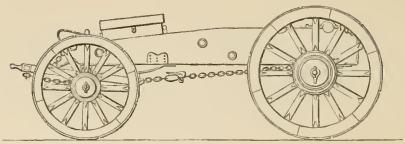
As for the 12-pounder gun, and 32-pounder howitzer, the carriages are like the field ones, except that the trail hooks up to a straight pintail, and that the limber carries three boxes.

All these carriages have two sets of trunnion holes, one for firing, the other for travelling.

(12). *Siege carriages* are formed of two brackets connected together by three *transoms*, the length of which varies with the nature of the gun. They have two sets of trunnion holes. The limber has no box of ammunition, the pintail resting on the top of the axletree bed. Part of the weight of the brackets is supported by a sweep bar, which also keeps the framework of the limber horizontal. The draught of the carriage is not taken by the pintail eye, but by a chain that

connects the axletree of the gun with that of the limber. The wheels of the

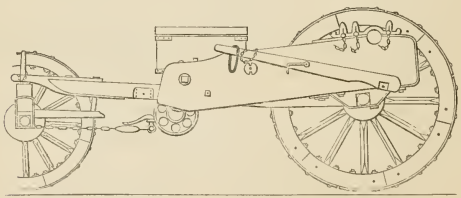
Fig. 12.



limber are smaller than those of the gun, so as to be capable of reversing in a small space.

(13). Howitzers (8′, 10′) have stronger carriages: the body consists of a perch trail with two short brackets, the perch limbering up to a straight pintail on the top of the limber; and there is but one set of trunnion holes. A wooden axletree, under the points of the brackets, with two trucks of iron, prevents the perch from

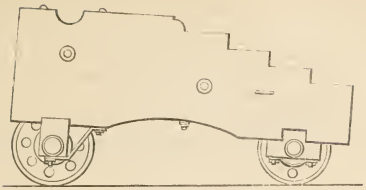
Fig. 13.



touching the ground, and facilitates the running up of the carriage. Two friction levers applied to the nave of the wheels diminish the recoil. The limber is similar to the former.

(14). Garrison guns are mounted, but not transported, on "*garrison standing carriages.*" These are made of wood, and consist of two brackets, connected by a transom, two bolts, and two axletrees, and are mounted on four small iron trucks. The guns are elevated by a quoin and a screw. There is no cap-square, because the recoil is not great, as in field pieces.

Fig. 14

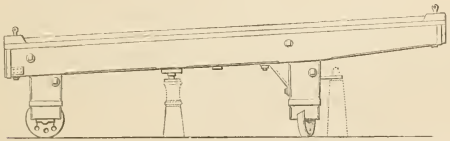


The carriage for howitzers is similar, but has blocks of wood instead of rear trucks, and is further strengthened by iron.

Iron carriages are also employed in the colonies.

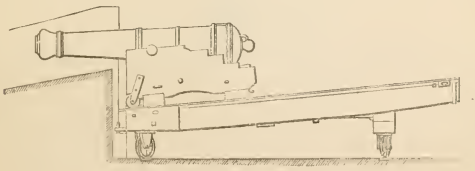
(15.) Garrison carriages are raised, so as to fire over a parapet, by means of traversing platforms, of which there are three kinds. The *common platform*, made of wood, and sometimes of iron, consists of two long side pieces placed upon four legs, having trucks that run upon a circular racer let into the ground. On the top of each side piece is a plank for the trucks of the gun carriage to run upon, whilst a riband placed inside both pieces, prevents the trucks from running off. Those platforms traverse in front, centre or rear, and have a slope of $\frac{1}{12}$ to diminish

Fig. 15.



the recoil. When a garrison carriage is mounted on such a platform, the two hind trucks are replaced by blocks of wood. The *dwarf* traversing platform exposes the guns less than the above. The ordinary garrison carriage is used with it, but

Fig. 16.



has blocks instead of axle-trees. In front of each bracket is a brass truck, which is of service when the rear of the carriage is hoisted up by the truck levers. (98.)

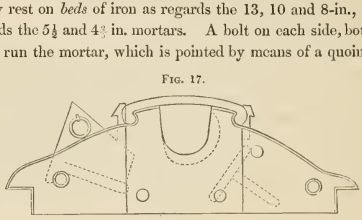
The *casemate* platform is low, has no legs in front, traverses on a racer let into the masonry, and has a carriage as above.

The carriages for the transport of heavy ordnance are the *sling cart*, *sling waggon*, *platform waggon*, and *trench cart*.

(16.) The naval carriages for heavy ordnance are distinguished into *common* ship carriage, *rear shock* carriage, *sliding* carriage, and *jamming* carriage. The light pieces have carriages similar to those of the field, besides carriages for boat service.

(17.) To complete this nomenclature, we may add that mortars have no carriage: they rest on *beds* of iron as regards the 13, 10 and 8-in., and on beds of wood as regards the $5\frac{1}{2}$ and $4\frac{2}{5}$ in. mortars. A bolt on each side, both in front and rear, serves to run the mortar, which is pointed by means of a quoin, up or back.

FIG. 17.



(18.) The *number of horses* allowed for the various pieces of ordnance varies; in the service, it is found advisable not to employ more than 12 horses for the heaviest ordnance. Thus a 24 or 32-pounder carriage is drawn by 12 horses; an 18-pounder by 12, a 12-pounder and a 9-pounder by 8, a 6-pounder by 6. In horse artillery, each horse has to draw about $4\frac{1}{2}$ cwt., in field batteries $4\frac{3}{4}$, and with heavy ordnance, from $5\frac{1}{2}$ to 7 cwt.

For field carriages, and those for light guns of position, double draught is employed, the off-horse being placed in the shaft; mountain artillery carriages have shafts for single draught; for siege carriages or heavy guns of position, four horses are harnessed abreast, and there are two pairs of shafts, one for each of the inside horses.

SECTION IV.—PROJECTILES.

The projectiles fired from ordnance are—shots, shells, shrapnels, carcasses, and balls.

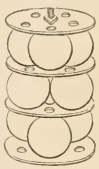
The shots may be classed into round shot (solid or hollow), grape, and common case or canister.

(19.) *Solid shot* are spheres of cast iron, and are fired from all guns except

shell guns. Those for field guns have wooden sabots. *Hollow shot*, are hollow spheres of cast iron fired from shell guns, and are chiefly used for naval service. Their diameter is great in comparison with their weight; and their relatively smaller momentum causes the formation of large apertures and numerous splinters.

(1.) *Grape shot* consists of a number of cast iron balls arranged in tiers, by means of three cast iron circular plates, and a bottom plate of wrought iron, the whole being secured firmly by a wrought iron pin that passes through the centres of the plates. There are from 3 to 5 shots in each tier, from 8 ozs. to 3 lbs. each, according to the calibre of the gun. It is only fired from iron guns. Grape shot is very destructive at ranges under 300 yards, and will even produce great effect at 600 yards.

Fig. 17*



(22.) *Common case* or *canister*, consists of a number of cast iron balls, placed in a tin cylinder having a wooden bottom. The number and size of the balls vary, they weigh from 2 ozs. to 1 lb. each. A field gun canister contains 41 balls of 2 ozs.; a 32-pounder howitzer, fires a case containing 258 balls of 2 ozs. Canister is fired both by guns and howitzers. The case for the 10 inch (sea) gun, has a cylinder of sheet iron, with an iron top and bottom.

Canister is effective at a distance of from 100 to 300 yards only.

(23.) Shells are hollow spheres of cast iron, with a hole to receive a fuze: they were formerly filled with just sufficient powder to burst them, but at present they are entirely filled, which causes the projectile to be less eccentric, its flight to be more regular, and the fragments to have a greater momentum. The length of the fuze (33), is calculated to cause the shell to burst at the proper distance. The thickness of metal is about $\frac{1}{6}$ of the diameter—to resist the shock of the discharge, and weighs nearly $\frac{3}{4}$ of the solid shot of equal diameter.

There are three kinds of common shells—

The *common shell*, which is provided with a sabot of wood, attached by a rivet to the bottom of the shell opposite the fuze hole, and destined to maintain the fuze in the axis of the bore when loading.

Fig. 18.

When such a shell is conveyed loaded, a gutta percha wad, driven through the fuze hole, keeps the powder dry, and is secured by a metal plug screwed into the fuze hole.

The *naval shell* is always carried loaded with its metallic fuze, and is similar to the former.

The *mortar shell* has no sabot. The shells for the 13 and 10-inch mortars, have two small rings or slugs on the sides of the fuze hole to facilitate loading.

Fig. 19.

(24.) A *shrapnel shell*, or spherical case shot, is a shell filled with musket balls, and a charge of powder to burst it. The thickness of the shell is about $\frac{1}{10}$ the diameter, and the weight is half that of a solid shot.

The bursting charge was poured loose among the bullets in the original shrapnel, which often caused premature explosions, it has been improved by Captain Boxer, who separated this charge from the balls.

In the improved shell (fig. 20), the powder is placed in a cylinder of metal, and the balls are kept steady by melted rosin poured into the interstices. In a further improved shrapnel by the same officer, called the *diaphragm shell* (fig. 21), the

Fig. 20.

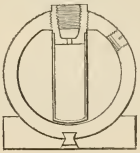
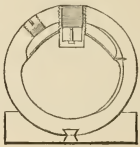


Fig. 21.



bursting charge is separated from the balls by a partition or diaphragm of wrought iron. The balls are harder, being made of an alloy of lead and antimony; the rosin is replaced by coal dust; and a coating of marine glue inside the shell, prevents this dust from mixing with the charge, should the diaphragm give way. The bursting of the shell is facilitated by four grooves running into the interior, from the fuze hole almost to the bottom. The fuze hole is fitted with a metal socket, into which the fuze is placed when the metal plug (23) used when

carrying the shell is removed. The bullets for field guns weigh 20 to the pound, those for heavy guns, 14. A shrapnel for a 6-pounder gun contains 29 bullets, for 12-pounders 62, for 32-pounders 151, for an 8-inch gun 338. Shrapnels do execution at considerable ranges, but the fuze should be regulated so that the shell may explode about fifty yards short of the object fired at; if either too long or too short, the effect is lost.

(25.) *Carcasses* are shells with three fuze holes or vents; they are filled with a certain composition, which being ignited by the discharge issues in strong flames out of the vents during about ten minutes, and sets fire to any combustible material it may fall upon. The thickness of metal is greater than in a common shell, on account of the three vents which weaken it. They are fired from any ordnance—generally mortars.

Fig. 22.

(26.) Balls are of two kinds: *Light-balls*,—either *ground light* (burning on the ground), or *suspended light* (burning while suspended in the air by means of a small parachute, the invention of Capt. Boxer), are fired from mortars. They are made of canvass or paper, and contain a composition which produces a bright light and burns a long time. They are employed at night to discover the movements of an enemy.

Fig. 23.

Smoke balls are similar projectiles; but the composition produces large volumes of smoke, which form a screen and obstruct the view. They are often employed to throw into mines.

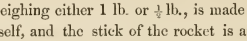
(27.) *Hand grenades* are small shells weighing 1 lb. 13 oz., filled with a bursting charge, and provided with a fuze 2¼ inches long. They may be thrown by the hand fifteen or twenty yards, and are employed in situations where the troops using them are secure from splinters. They are sometimes quilted and tied together with their fuzes outwards, and fired at small ranges with mortars. Hand grenades are also made of thick glass.

Fig. 24.

(28.) A *rocket* is a cylindrical case of paper or iron filled with composition; to one end a cylindro-conoidal head is attached, while at the other end (the choke or neck) there are several apertures or vents for the escape of the gases produced by the combustion. A conical hollow, the base of which coincides with that of the rocket, is left empty about the axis of the composition, in order that a great surface may be ignited at the same time, thereby generating a large quantity of gas which exerts a pressure on the interior of the rocket. The pressure on the head being greater than that on the base on account of the vents, the rocket moves forwards. It is fired through a tube, so that it is propelled in the required direction. A stick attached to the base counteracts the tendency to rotation, and maintains the projectile in its right direction. There are in the service two kinds of rockets.

The *signal rocket*, weighing either 1 lb. or ½ lb., is made of paper: there is only one vent in the axis itself, and the stick of the rocket is attached to the side. It is fired vertically, and

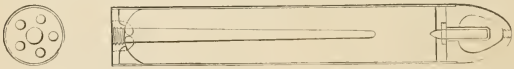
FIG. 25.



when the composition is burnt, the bursting charge ignites the *stars* put into the head. A rocket of 1 to 2 inches in diameter rises from 450 to 600 yards; if of 2 or 3 inches diameter, from 1000 to 1200. The time of flight is from seven to ten seconds, and the signal may be seen at a distance of 40 miles.

The *Congreve rocket*, of which there are four kinds in the service, the 3-pounder, 6-pounder, 12-pounder, and 24-pounder, has a case of sheet iron. A hollow cylindro-conoidal iron head is screwed on the top, to act as shot if empty, or as shell if filled with bursting powder. Some conical heads with vents may also be substituted for the ordinary pattern, to act as carcasses. The base of the shell

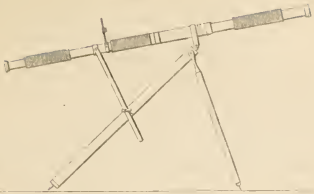
FIG. 26.



carries a fuze, and the apex has a small hole through which the bursting charge is introduced, and a bore bit is inserted to pierce into the fuze composition (33). A metal plug closes the apex. The bottom of the rocket is closed by an iron plate having a centre hole, into which the stick is screwed, and five equidistant vents. The composition is stronger than that in signal rockets.

They are fired, at the proper elevation, by means of iron tubes raised above ground by legs, so as to keep the sticks from touching it. The elevation is about 1° for every 100 yards of the intended range. In windy weather they should be

Fig. 27.



fired leeward. They are fired against troops presenting a large front, or are employed to set buildings on fire; but the accuracy of their flight cannot be relied on.

Rockets are carried in the field in a special waggon attached to each battery.

(29.) The charge of powder is fixed for guns and howitzers, that for mortars is variable.

The *service charge* is in general one-third of the weight of the projectile for heavy and medium guns, and $\frac{1}{4}$th for light guns. Iron howitzers have a charge of $\frac{1}{7\cdot5}$th, and brass howitzers a charge of from $\frac{1}{5}$th to $\frac{1}{6}$th of the weight of the projectile. In ricochet fire this charge is much altered, and varies from $\frac{1}{20}$ to $\frac{1}{30}$. In the navy there are three kinds of charges, the distant, full, and reduced.

The charge is contained in *cartridges* made of serge, which are conveyed in boxes. For the 3-pounder gun the projectile is attached to the cartridge.

The ordinary wads are *junk* or oakum rolled up in a cylindrical form, fitting the gun rather tightly, and *grummet* or a piece of rope formed like a ring of an external diameter equal to the calibre of the gun. The junks are used for hot shot and brass pieces. The grummets however are preferable, since they cause less deviation.

The charge is ignited by means of a tube placed in the vent hole. Of tubes there are six different kinds in the service: the *common quill tube*, the Dutch or *paper tubes*, and the *common metal tube*, filled with meal powder, are fired with a port-fire; the *detonating quill tube*, is used for guns which have a lock fixed to the vent plate; the hammer of the lock ignites the fulminating composition on falling; the *metal* or *quill friction* tubes contain a similar composition, and are fired by means of a lanyard hooked to a ring at the head of the tube; the ring

Fig. 28.

being pulled, sufficient friction is produced on the composition by a rough strip of copper attached to the ring. Finally, *galvanic tubes* are also used when the guns are "proved," and ignited by means of a galvanic battery.

Portfires are of two kinds: the common portfire burning at the rate of one inch per minute, is made of a paper case, 16 inches long, which is filled with composition; the slow portfire is paper impregnated with saltpetre. It is formed into a cylinder 16 inches long, and lasts from 3 to 4 hours.

Quick match is cotton coated with a composition of powder and gum; *slow match* is hempen rope loosely twisted and dipped in a solution of lime and saltpetre; one yard burns three hours. Another sort burning under water, and called "*Bickford's fuze*," burns at the rate of 12 feet per 5 minutes.

Shell fuzes are attached to the shells for the purpose of igniting the bursting charge *at a precise moment*. There are in the service three different kinds of fuzes, the *time* or Boxer's fuze; the *concussion* or Freeburn's fuze; the *percussion* or Moorsom's fuze (see 35).

The *time fuze* consists of a conical case of *wood*, for land service, and of brass or bronze for naval shells.

The wooden fuze contains a composition that burns regularly, at the rate of one inch in five seconds, so that any length may be given to it, by merely boring a hole through the case, which will allow the flame to pass from the case to the bursting charge. There are special fuzes for common shells, shrapnels, and mortars. The naval (metal) fuzes are also of two sorts, long and short.

Freeburn's concussion fuze is so constructed, that the concussion produced when the shell strikes the object, drives the ignited composition out of the fuze into the bursting charge. The case is of wood.

Moorsom's percussion fuze is made of metal, and contains 3 cylindrical chambers, in each of which is suspended, by thin copper wire, a hammer, which, falling on a detonating composition, when the shell strikes an object, causes the bursting charge to be ignited. These are liable to accidents.

A new fuze is now proposed; it is invented by Mr. Pettman.

Nature of piece.	Weight.	Length.	Diameter of bore.	Windage.	Service charge for shot or diaphragm shell.	Ditto for common shell.	Weight of shot.	Common Shell.		Case.		Shrapnels Diaphragm.		Grape.	
								Empty.	Filled, nearly.	Empty.	Filled.	Empty.	Filled.	Empty.	Filled.
	cwt.	ft. in.	inches.	inches.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs. oz.	lbs.	lbs.
10-inch Shell Gun	86	9 4	10	·16	12 0	12 0	84 0	86 0	93 0	11 0	86 0	...	...	11	83
8-inch „	65	9 0	8	·125	10 0	10 0	56 0	46 0	50 0	6 0	51 0	37 0	61 0	...	...
8-inch „	60	8 10	8	·125	10 0	10 0	...	...	...	...	...	...	...	...	...
8 inch „	52	8 0	8	·125	8 0	8 0	...	...	...	...	...	...	...	...	...
8-inch „	50	6 8½	8	·125	8 0	8 0	...	...	...	...	...	...	...	...	...
68-pounder Gun	112	10 10	8·12	·2	18 0	10 0	68 0	46 0	50 0	...	...	37 0	61 0	21	68
68-pounder „	95	10 0	8·12	·2	16 0	10 0	...	...	...	...	...	...	...	...	...
56-pounder „	98	11 0	7·65	·175	14 0	10 0	56 0	39 0	43 0	6 0	56 0	...	...	20	56
42-pounder „	67	9 6	6·97	·2	10 8	10 8	42 0	28 0	31 0	4 0	47 0	...	...	12	48
32-pounder „	58	9 6	6·36	·198	10 0	10 0	32 0	22 0	24 0	3 0	36 0	18 0	29 0	9	36
32-pounder „	56	9 0	6·40	·233	10 0	10 0	...	...	...	...	...	...	...	...	...
32-pounder „	50	9 0	6·36	·198	8 0	8 0	...	...	...	...	...	...	...	...	...
24-pounder „	50	9 6	5·82	·211	8 0	8 0	24 0	16 0	18 0	3 0	25 0	13 0	21 0	6	26
24-pounder „	48	9 0	5·82	·211	8 0	8 0	...	...	...	...	...	...	...	...	...
18-pounder „	42	9 0	5·29	·193	6 0	6 0	18 0	12 0	13 0	2 0	19 0	10 0	17 0	6	19
10-inch Howitzer	41	5 0	10	·16	...	7 0	...	...	...	9 0	94 0	...	...	Carcasses.	
8-inch „	21	4 0	8	·14	3 0	4 0	...	...	...	...	6 0	38 0	...	Empty.	Full.
13-inch Mortar (Land).	36	3 3·6	13	·16	...	...	...	194 0	205 0	...	...	...	...	220	233
10-inch „ ...	18	2 7·5	10	·16	...	...	...	86 0	91 0	...	...	...	...	96	102
8-inch „ ...	9	2 1·2	8	·14	...	...	...	46 0	49 0	...	...	...	...	48	53
12-pounder Gun	18	6 0	4·62	·1	4 0	4 0	12 0	...	...	1 0	18 0	6 0	11 0	4	13
9-pounder „	13½	6 0	4.2	·1	2 8	...	9 0	...	...	0 15	14 0	5 0	8 0	3	10
6-pounder „	6	5 0	3·67	·1	1 8	...	6 0	...	...	0 11	9 0	3 0	6 0	2	6
3-pounder „	2½	3 0	2·92	·1	0 10	...	3 0	...	...	0 7	4 0	...	...	...	...
32-pounder Howitzer ...	17½	5 3	6·3	·123	3 0	3 0	...	22 0	25 0	2 0	23 0	...	...	...	...
24-pounder „ ...	13	4 8·6	5½	·125	2 8	2 8	...	16 0	18 0	2 0	14 0	...	...	...	...
12-pounder „ ...	6½	3 9·2	4⅝	·126	1 4	1 4	...	8 0	9 0	1 0	7 0	...	...	...	...
4⅘-inch „ ...	2½	1 10·6	4⅝	·066	...	0 8	...	8 0	9 0	1 0	7 0	...	...	...	...
5⅓-inch Mortar	1½	1 3·1	5⅓	·025	...	...	...	16 0	18 0	...	...	...	...	...	...
4⅘-inch „	¾	1 0·7	4⅝	·066	...	...	...	8 0	9 0	...	...	...	...	...	...

SECTION V.—Rifled Ordnance.

A revolution is now going on in artillery by the introduction of rifled ordnance. Not only is an increased accuracy of fire, with greater range and penetration, obtained with comparatively small charges; but the equipment and ammunition of field guns are much simplified, as will hereafter be explained.

(34). In 1846 Major *Cavalli*, a Sardinian officer, invented a breech-loading rifled gun; the bore was cylindrical, 6½ inches in diameter, and rifled with two grooves. At the same time Baron *Wahrendorff*, a Swede, invented a similar gun, with a bore of 6·37 inches. The projectile of Cavalli was cylindro-conical, that of

Fig. 29.

Fig. 30.

Wahrendorff cylindro-conoidal, and both had two projections to fit into the grooves; their weight was about 69 pounds. Some experiments were made at Shoeburyness in 1850, in order to try and compare these guns with a 32-pounder of 56 cwt., when it was found that for elevations under 5°, and with charges of 8 or 10 pounds, the accuracy and ranges were nearly the same. With greater elevation the foreign guns ranged further, the excess at 15° with 8lbs. charge, being 790, and with 10lbs., 1100 yards. The gun of Wahrendorff stood well, that of Cavalli very soon became unserviceable.

In 1851 experiments were made with *Lancaster* guns; these were service guns *bored into rifled guns*, the bore being an elliptical helix, the major and minor axes of which had ¼ of a revolution, increasing gradually from the bottom of the bore to the muzzle, and forming what is termed a "gaining twist." The projectile is elliptical in section, cylindro-conoidal in form, and hollow. In these experiments, as well as in those made at Malta in 1859, it was found that the shell is liable to jam in the bore and burst the gun, whilst great irregularities occur in the range.

(35). In France some rifled guns, of the invention of *Louis Napoleon*, were introduced into the service (1859), and, for the sake of economy, were obtained,

by the transformation of smooth-bored brass pieces. They are muzzle loading,

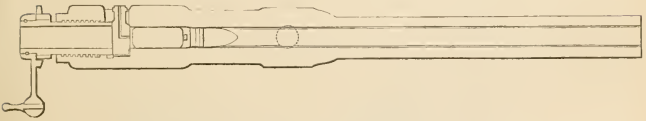
Fig. 31.

with 6 grooves, having a turn in 59 inches. The projectile is cylindro conoidal, and has two sets of buttons or projections, 6 in each set, fitting into the grooves of the bore. The field shell gun (canon obusier), replaces the four kinds of ordnance hitherto employed, viz., the 12-pounder and 8-pounder guns, the 6 inch and the 24-pounder howitzers. The calibre is 3·6 inches; the gun weighs from 5 to 6 cwt.; the charge is 1lb.; the projectile weighs 9lbs. Instead of 9 projectiles, there are only 4, and there is but one sort of carriage and ordnance. There is also a siege gun of the calibre of a 12-pounder.

(35). The *Armstrong* gun, proposed in 1854, is now adopted in the service; two batteries of 12-pounders, of 6 cwt., were sent to China in 1859, and forty 100-pounders were lately sent to Portsmouth.

The Armstrong gun is made of strips of wrought iron, wound spirally round and welded together, as in sporting gun barrels, by which process the strain arising from the discharge is received by the metal in the direction of its fibres, and, therefore, in the direction in which it has the greatest tenacity. The bore is cylindrical, with a chamber somewhat larger to receive the charge and projectile. The number of grooves varies with the nature of the gun, and often exceeds 40. They have one turn in twice the length of the bore. A breech piece, with a mitred face, fitting exactly into a similar face at the end of the bore, carries the

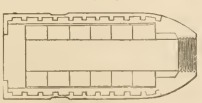
Fig. 32.



vent, and is dropped into a recess, thereby closing that bore; the fitting surfaces are of copper. A cylinder of iron, with a screw turned on the outside, works in a female screw in the breech, and presses tightly the breech piece.

The projectile is hollow, and may serve as shot, shell, case, or shrapnel. It is a pointed cylinder, formed of 42 cylindro-segments of cast-iron, externally coated

Fig. 33.



with lead. When fired, the lead is crushed into the grooves, so that there is no windage, the point of the projectile remaining foremost during the whole time of flight. This result permits the application of a percussion fuze to the point when the projectile is used as a shell. The point is therefore provided with a female screw, to receive a plug, a time fuze, or a percussion fuze, according as the projectile serves as shot, shrapnel, or shell. The charge of powder is about $\frac{1}{8}$ that of the projectile.

The carriage is similar to that of a field gun, but lighter. It has in addition a

Fig. 34.

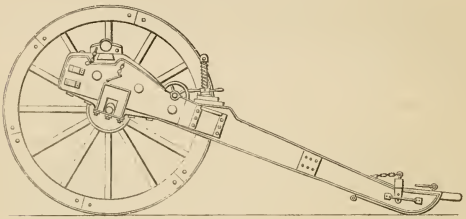
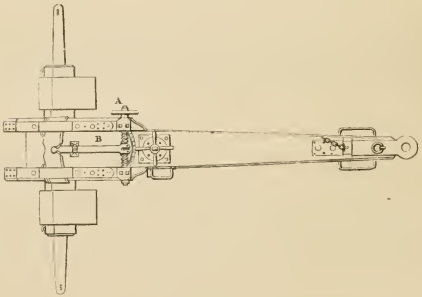


Fig. 35.



mechanism A B, which allows minute alterations in the pointing. A screw, turned by a handle, is connected by a bar with moveable trunnion holes, so that a horizontal motion round a centre between them may be given to the trunnions of the gun. It is also provided with an improved tangent scale.

The 12-pounder, of 6 cwt., has a point blank of 300 yards ; the ranges are with 1°, 700 yards; 2°, 900; 3°, 1,200; 4°, 1,600; 5°, 1,900; 6°, 2,200; 7°, 2,400; 8°, 2,800; 9°, 2,900. Several other calibres are likely to be adopted. The 100-pounders, 10 feet long, weighing 80 cwt., are intended for the navy, for coast defences, or for garrison, and whenever very powerful ordnance are required.

The 40-pounders, 10 feet long, weighing 31¾ cwt., will most probably be employed as siege, garrison, and navy guns, and for coast batteries. The long 25-pounders, 8 feet long, weighing 16¼ cwt., and the short 25 pounders, 5 feet 6 inches long, weighing 12½ cwt., are intended, the first for guns of position, the second for boat service. The 12-pounders, 7 feet long, weighing 8½ cwt., are for field guns, the projectile weighing 12lbs., for field batteries, and 9lbs. for horse artillery. The 6-pounders, 5 feet long, weighing 3¾ cwt., are for mountain service.

(36). Another breech-loading rifled gun, due to *Whitworth*, is now competing with the Armstrong. There is a 3-pounder, of 208lbs. weight, a 12-pounder of 8 cwt., and an 80-pounder of 80 cwt.

The bore is an hexagonal spiral, the inclination of the spire varying with the diameter; the twist is rather rapid, in order to overcome the tendency of the projectile, which is long, to turn over in its flight. The breech is closed by a cap, which screws on the outside, and works in an iron hoop, attached by a hinge to the side of the breech. The cap is opened back for loading, after which it is shut like a door, and secured on the breech by a handle made for the purpose. The vent is in the centre of the cap. The projectile is hexagonal, and of cast-iron. The charge is $\frac{1}{6}$.

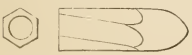


Fig. 36.

The range and accuracy of these guns is said to be very great, the 3-pounder carrying above 5¼ miles.

(37). In 1851 the old musket was replaced by a rifle; and in 1853 entirely superseded by the *Enfield rifle*.

It is 6 feet 0·5 inches long, including bayonet, and weighs 9 lbs. 3 ozs. The length of the barrel is 3 feet 3 inches; it weighs 4 lbs. 2 ozs., and its bore measures ·577 inches: it has three grooves, each forming a spiral of one turn in 6 feet. It is sighted to 900 yards, but its practice is good at larger ranges. The charge of powder weighs 2½ drams.

Rifle corps and sergeants of infantry have a shorter rifle, with sword bayonet: its length is 5 feet 11¼ inches, it weighs 9 lbs. 11⅜ ozs., and the barrel measures only 2 feet 9 inches. It is made exactly on the same principle, and is used with the same ammunition as the former.

The bullet is elongated, ·55 inches in diameter, and weighs 530 grains.

The penetration of the projectile exceeds that of the old bullet; at 100 yards it goes through 19 inches of stiff clay, and at 30 yards passes through 12 planks of elm half an inch thick, and placed half an inch apart.

(38). It is only step by step that this improvement of the rifle has taken place.

Fig 37.

In 1827 Mr. Delvigne, a French officer, invented a rifle with a small chamber at the bottom of the bore; the spherical bullet fitting loosely in the barrel, rested on the shoulder of that chamber, and was expanded so as to fill the grooves by a smart blow from a heavy ramrod. This, however, disfigured the bullet, and in 1842, Colonel Thouvenin, of the French service, attempted something else. A "tige" of steel was screwed to the bottom of the bore; the charge being placed round it, and the spherical bullet on the top, it was expanded into the grooves by a blow. The projectile receiving the impulse obliquely could not give accuracy.

These two rifles had this serious inconvenience, that the bullet could not be

Fig. 38.

fixed to the cartridge; but Mr. Delvigne introduced a cylindro-ogival bullet, with a groove round it to fix the cartridge, and in 1846 this projectile was adopted in France, together with the "carabine à tige;" the head of the ramrod being scooped out to fit the point of the bullet while loading. The tige frequently breaking, and the barrel rapidly becoming foul, a new bullet, of the invention of Minié, soon obviated these defects, and the tige was dispensed with. Minié's bullet is cylindro-conoidal, with a conical hollow at the base, into which is fitted an iron cup. The powder acting on this cup (fig. 39), drives it up the narrow end of the hollow, and causes the surface of the lead to expand into the grooves. It was introduced into England in 1851, but in 1853 was replaced by the Pritchet bullet (fig. 40). This projectile had no cup, and was made of such a length that the powder acting suddenly on its base, drove it up slightly, before the inertia of the point was overcome, thus causing it to expand into the grooves, near its shoulder, the hollow being merely intended to throw the centre of gravity forward. It, however, fouled the piece, and Colonel Hay improved it by introducing a plug of box wood into the hollow (fig. 41); this prevents the sides of the bullet from collapsing when it leaves the barrel, and is found to prevent the barrel from fouling.

Fig. 39.

Fig. 40.

Fig. 41.

The Pritchet bullet, improved by Colonel Hay, is now employed in the service.

Other projectiles have been proposed—Colonel Jacob's (of the Bombay Artillery) bullets (fig. 42) gave long ranges, but required great charges. A solid bullet,

Fig. 42.

Fig. 43.

(fig. 43) with two deep annular grooves, invented by Wilkinson, has been adopted in Austria. Mr. Whitworth's bullet and rifle are on the same principle as his rifled gun, &c.

(39). Besides the *Enfield rifle* there are in the service: the *Lancaster rifle*, employed by the corps of Sappers. It is made on the same plan as his rifled guns. The total weight is 9 lbs. 2 ozs., the length of barrel is 2 feet 8 inches, that of the sword bayonet 2 feet. Its range is good, and as the bore is smooth it does not foul, but the bullet is liable to strip.

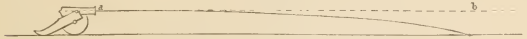
There are also the Artillery rifle, the revolvers of Dean and Adams, a cavalry carbine, and some breech-loading carbines on trial.

The number of rounds carried by each man is 60, together with 75 caps. They weigh 5 lbs. 8 oz. The reserve for small arms' ammunition is divided into three parts: the 1st and 2nd reserves, conveyed in ammunition wagons, are attached to the field batteries of each division. The wagons are provided with cradles and ladders to transport the ammunition wherever required. The 3rd reserve follows at two days march in the depôts of the military store department.

SECTION VI.—Gunnery.

(40). The *point blank* range of a gun is the range *a b* obtained at the first graze of the shot, when the piece placed on its carriage is fired with the service

Fig. 44.



charge, on a horizontal plane, the axis also being horizontal. A gun is "*laid point blank*" when the production of its axis will pass through the object aimed at, whatever be the elevation or depression with the horizon.

(41). As the axis is not visible, its position must be obtained practically: this is done by means of the *line of metal* or visual line joining the notches cut on the

highest points of the base ring, and the swell of the muzzle; when the trunnions are horizontal, this line is in the same vertical plane with the axis of the gun.

In guns which have no dispart patch, when the line of metal is pointed upon an object, the axis passes over the object aimed at, and the elevation thus obtained

Fig. 45.

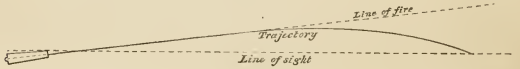
is called *line of metal elevation;* it is 1° in light field guns, 1¼° in medium ditto, 1½° in ordinary iron guns, &c.

(42). As the charge of a gun is fired, the initial velocity of the projectile is constant, the range will therefore depend upon the inclination of the axis to the ground. The action of gravity causing the projectile to descend continually after leaving the bore, it is necessary, in order to strike an object, to direct the axis at a point more or less above the object, according as it is more or less distant.

The elevation of the axis is obtained by means of a *tangent scale,* of which there are several sorts in the service; the ordinary scale consists of a rod, which, sliding up and down in a groove behind the vent, can be fixed in any position, by means of a screw. It is divided into quarter degrees, as far as 8°.

The *line of sight* is the line passing through the top of the tangent scale, the notch of the muzzle and the object fired at.

Fig. 46.



The *angle of elevation* is the angle which the line of fire, or axis produced, makes with the line of sight.

The angle of elevation may be given to guns by other means than the tangent scales: thus in field guns it may be obtained as far as 3° by the *quarter sights,* or by cuts on the sides of the base ring; the top notch, with another on the swell of the muzzle, giving a line of sight parallel to the axis. A *spirit level quadrant,* or a *gunner's quadrant,* may also be employed.

(43). *Trajectory* is the path described by the centre of gravity of the projectile; it intersects the line of sight in two points, one near the muzzle, the other at the object fired at.

(44). Mortars are laid by means of a plummet, held in the hand just behind the piece; the string being made to coincide with two pickets planted on the parapet, in the direction of the object, the mortar is traversed until the line of the plummet covers the central line of the mortar, indicated by a notch on the

muzzle, and another behind the vent. The elevation is generally 45°, and the range varies with the charge of powder.

Tables of practice are constructed, giving the ranges of the various kinds of ordnance with the corresponding elevation, for the purpose of securing good practice: we give two of these tables.

RANGE OF IRON ORDNANCE.

	Point Blank.	Elevation of							
	Yards.	1°	2°	3°	4°	5°	6°	8°	
10-in. Siege Gun	315	635	935	1205	1450	1665	1825	2095	Hollow Shot of 86 lbs.
8-in. „ of 65 cwt.	340	659	1000	1300	1600	1850	2050	2357	„ of 56 lbs.
8-in. „ of 60 cwt.	320	660	960	1250	1500	1720	1910	2220	Shell of 51 lbs., filled
8-in. „ of 52 cwt.	290	530	820	1080	1340	1550	1860	2080	Hollow of 56 lbs.
68-pounder of 112 cwt.	370	900	1170	1660	1860	2140	2400	2740	Solid Shot.
68-pounder of 95 cwt.	320	700	1070	1410	1710	1930	2140	2540	„
56-pounder of 98 cwt.	390	840	1250	1700	1950	2140	2330	2650	„
42-pounder of 67 cwt.	300	730	1120	1420	1660	1880	2110	2500	„
32-pounder of 58 cwt.	400	820	1200	1520	1810	2050	2250	2610	„
32-pounder of 56 cwt.	370	779	1160	1460	1690	1910	2110	2460	„
32-pounder of 50 cwt.	346	747	1173	1435	1698	1900	2127	2453	„
24-pounder* of 50 cwt.	360	750	1120	1440	1630	1840	1950	2230	„
18-pounder of 42 cwt.	350	690	990	1270	1500	1710	1890	2130	„
10-in. Howitzer.....	323	511	709	934	1073	1270	1406	1848	Shell.

* A 24-pounder gun, fired at an elevation of 45°, with a charge of 6 lbs., carries 4500 yards.
An 18-pounder „ „ 40° „ 6 lbs. „ 4200 yards.

RANGE OF BRASS ORDNANCE.

	Point Blank.	Elevation of							
	Yards.	1°	2°	3°	4°	5°	6°	8°	
12-pounder of 18 cwt.	300	700	1000	1200	1400	1600	1800	...	Shot.
9-pounder of 13½ cwt.	300	680	960	1190	1400	1590	1750	...	„
6-pounder of 6 cwt.	300	620	890	1100	1280	1450	1600	...	„
32-pounder Howitzer. .	300	500	700	900	1100	1300	1400	...	Common Shell.
24-pounder ditto ...	270	520	760	960	1160	1350	1520	...	„
12-pounder ditto ...	200	420	630	800	970	1135	1290	...	„

RANGES OF MORTARS (CHARGE OF POWDER).

Distance.	13-inch.			10-inch.			8-inch.			5½-inch.			4⅘-inch.		
	lbs.	oz.	drms.	lbs.	oz.	drms.	lbs.	oz.	drms.	lbs.	oz.	drms.	lbs.	oz.	drms.
200 yards	...			...			...			...			0	2	0
400 yards	1	12	0	0	15	0	0	9	8	0	5	0	0	2	12
600 yards	2	5	0	1	4	8	0	13	12	0	6	0	0	3	12
800 yards	2	13	8	1	10	0	1	0	10	0	7	1	0	4	15
1000 yards	3	7	0	1	14	0	1	3	8	0	8	6	...		
1200 yards	4	0	0	2	4	0	1	6	0	...			...		
2000 yards	6	2	0	3	2	0	2	0	0	...			...		
2400 yards	...			4	0	0	...			...			...		
2900 yards	9	0	0	...			...			...			...		
3400 yards	12	0	0	8	0	0	...			...			...		
4500 yards	...			20	0	0	...			...			...		
4700 yards	25	0	0	...			...			...			...		

RANGE OF CASE SHOT FROM FIELD PIECES.

	Point blank.	1°	2°
12-pounder Gun	200	300	400
9-pounder „	150	250	350
6-pounder „	100	200	300
32-pounder Howitzer	200	300	400
24-pounder „	150	250	350
12-pounder „	100	200	300

A sufficient number of experiments has not yet been made to determine the *penetration* of the new ordnance. We, therefore, confine ourselves to the old ordnance, and give an extract of the results furnished by the experiments made at Metz in 1834, which are generally acknowledged as a good authority.

		Penetration in								
		Masonry.			Oak.			Earth.		
Distances		25 m	300	1000	25	300	1000	25	300	1000
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Guns . . .	36 pounds.	26·77	22·24	12·20	66·35	54·33	31·49	109·05	93·30	69·48
	24 „	25·59	20·30	10·82	62·99	45·08	27·55	108·26	77·55	60·82
	16 „	22·44	15·15	7·67	54·72	37·40	19·68	96·48	66·53	50·39
	12 „	20·89	13·58	6·10	46·06	33·27	14·56	64·96	49·01	35·03
	8 „	17·74	11·61	4·13	39.37	28·74	10·62	53·29	43·30	28·74
Howitzers* . .	22 centim.	...	...	...	28·34	17·74	9·05	48·42	33·85	23·22
	16 „	...	...	...	33·27	20·50	9·84	52·95	35·03	22·04
	15 „	...	...	...	27·55	20·11	6·29	44·48	32·67	18·14
	12 „	...	...	...	14·96	8·26	3·93	27·16	21·29	10·23
Mortars fired at an elevation of 54° .	32 „	at 600 mètres		4·33		10·62			21·65	
	27 „			3·93		9·84			19·68	
	22 „			3·14		5·90			11·81	

* Shells and bombs are named from their diameter, expressed in centimètres. A centimètre = 0·39371 inch. The French metre = 39·37079 inches.

The above results must be multiplied—

In masonry, by 1·25, when old,
„ 1·75, when of bricks.

In wood, by 1· for beech, yoke elm, ash.
„ 1·3 for elm.
„ 1·8 for pine and birch.
„ 2· for poplar.

In earth, by ·63 for sand mixed with gravel.
„ ·87 for ditto, but lighter.
„ 1·09 for mould, or the above rammed in.
„ 1·44 for clay.
„ 1·50 for light soils.
„ 1·90 for ditto, recently rammed in.

With regard to the Enfield rifle, its extreme penetration into earth has been found to be 17 inches at 200 yards, and 19 inches at 20 yards. This penetration should be multiplied by ·16 for oak; ·33 for elm; ·76 for pine. The shot penetrates 12 inches into sandbag, passes through a fascine and 8 inches of earth besides, and is stopped by a gabion.

(46.) For the right understanding of the text, it is necessary that the student should be familiar with the various names given to the fire of musketry and artillery, according to its direction and nature.

The fire of artillery and musketry, receives the name of *direct* fire, when the projectile strikes perpendicularly the outside of a work or the front of the enemy. (1.)

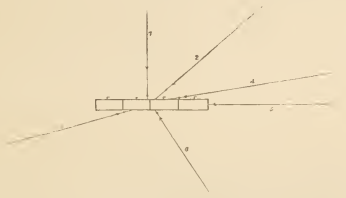
Oblique fire, when it strikes it obliquely. (2.)

Slanting fire (feu d' écharpe), when it strikes it at a very small angle, either in front or rear. (3, 4.)

Enfilade fire, when it is directed on the flank of a line of troops, from one end to the other, or along the banquette or rampart of a work. (5.)

Reverse fire, when the projectile strikes the rear of a line or the interior of a work. (6.)

Fig. 47.



Pitching fire, when the shot is projected against an object, covered in front by a work or obstacle, the ordnance being fired at full charge.

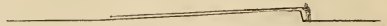
Fig. 48.

Plunging fire, when it comes from a commanding position.

Fig. 49.

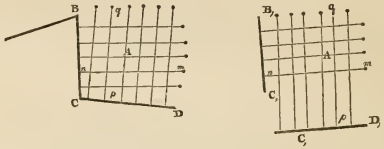
Grazing fire, when it sweeps close to the surface of the ground.

Fig. 50.



Flanking fire, when it is parallel to the front of a line or of a work. Thus if B C, C D, represent a work, B′ C′, C′ D′, lines of troops, the fires *m n*, *p q*, are called flanking. The space A is exposed to what is called *cross fire*, and we say that the line B C, flanks the line C D, and *vice versa*.

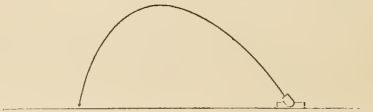
Fig. 51.



Besides these various fires which may be called horizontal, there are two other kinds peculiar to artillery.

Vertical fire, that of a mortar or a piece of ordnance fired with an elevation of 45°.

Fig. 52.



Ricochet fire, that of a gun or howitzer fired at a small angle, and with a reduced charge, the shot bounding along.

Fig. 53.

This description of fire applied by Vauban, 1797, at the siege of Ath, is chiefly employed for enfilading lines of troops, which are covered by some obstacle, and for destroying the guns that are mounted along the rampart of a fortress.

Ricochet is most efficient at 600 yards; in reducing the charge and giving an elevation to the piece, the projectile has a low velocity, and describes a high curve, which permits it to graze immediately after clearing the obstacle or parapet when firing against troops or guns.

The charge varies from $\frac{1}{18}$ to $\frac{1}{32}$ of the service charge; the maximum elevation for field guns is 3°, for siege guns 10°. In general the piece should be pointed from 6° to 9° above the parapet. The maximum elevation on water is 7°.

The following table is the result of practice at 600 yards.

24-pounder	charge	$\frac{1}{32}$	elevation $9\frac{1}{2}$°
18-pounder	,,	$\frac{1}{18}$	,, 5 °
24-pounder Howitzer .	,,	$\frac{1}{32}$	,, $6\frac{1}{2}$°
12-pounder ,, .	,,	$\frac{1}{19}$	,, $5\frac{3}{4}$°
10-inch ,, .	,,	$\frac{1}{24}$	,, $5\frac{1}{2}$°
8-inch ,, .	,,	$\frac{1}{24}$	,, $6\frac{1}{2}$°

CHAPTER II.

PRINCIPLES OF FORTIFICATION.

(47.) *Fortification* is employed for the purpose of enabling a body of men to resist with advantage the attack of a greater force.

It is either *Natural* or *Artificial.*

A chain of mountains, the sea, a river, are natural fortifications; whilst any work made by the hand of man is artificial. To the latter only we shall direct our attention.

It has been divided into *Permanent* and *Temporary,* or *Field Fortification.* As the name implies, permanent works are intended to stand for ages, as those that surround arsenals, and frontier places; whilst fieldworks are thrown up merely for a time, to occupy or defend a position, or to protect a bridge or a village.

(48.) It ought never to be lost sight of that in every description of warfare fortification is only an accessory, destined to increase the power of resistance of troops; and that works, particularly in the field, are only resorted to when we are weaker than our adversary. Fortification should not, therefore, paralyse the action of the troops, as has too often been the case, but give full scope to their efficacy.

Cavalry can only act offensively; infantry and artillery can act both on the offensive and the defensive, and for the latter alone is fortification employed, which should at the same time protect them, and enable them to concentrate their fire so as to give it its fullest effect, conditions concisely expressed by a celebrated engineer, 'it must *cover and flank.*' To these we might add, it must also *make the most of the ground,* for in fortification still more than in tactics, it is true that bravery is worth more than numbers; but the nature of the ground is often of more use than bravery.

(49.) Fortification is had recourse to by a defensive army to cover its front and flanks, more especially to protect its rear, when, extending in a long line,

---

* Cœhorn.

it is liable to the contingency of being turned; to secure its magazines and the arrival of its convoys, to defend its bridges and the defiles situated on its line of retreat.

An offensive army cannot be superior at every point, and however powerful, it must also secure its flanks and rear; the armies of siege more particularly require fortification to resist the sorties and the attacks of an army of relief.

SECTION I.—Ditch and Covering Mass.

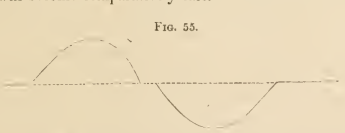
(50.) Fortification is the most ancient of all the arts of war; nature itself has pointed it out to us. The first man attacked by an enemy stronger than himself, in the consciousness of his inferiority, sought a remedy for it. A bush, a rock, a trunk of a tree must have served him as a fortification. To the present day we find savages possessed of no other; and we ourselves employ this primitive fortification in partial and sudden attacks. The natural hedge led us to the idea of forming artificial ones or abattis, the rock taught us to construct walls, and the ravine a parapet made of the earth extracted from a ditch. This kind of fortification protected the first houses against the attacks of wild beasts, and afterwards against men.*

Let us suppose a body of men in an open country threatened by a superior force, the first idea that will present itself will undoubtedly be to find a means to stop its advance: a *ditch* will answer this purpose.

Fig. 54.

Still the superiority of numbers will soon tell by a more deadly fire; a cover is therefore necessary, and if the earth extracted from the ditch is thrown up in a heap, the men will become comparatively safe.

Fig. 55.



Yet, if they remain inactive behind such a mask, the enemy would soon overcome the obstacle; but if this *covering mass* is constructed in such a way as to allow of

* *Encyclopédie*, Diderot.

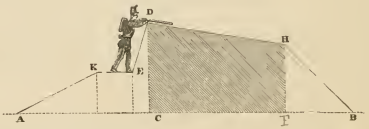
the defenders firing over it, then the attacking party becomes exposed, and the inequality of numbers partially remedied. All fortification consists thus of two distinct parts, a ditch and a covering mass.

Fig. 56.

The earth extracted from the ditch would not resist projectiles, and would soon be penetrated by rain and scattered by wind, if it were not rammed in and shaped regularly.

In the annexed diagram we give the representation of the covering mass, as it is now constructed.

Fig. 57.



The line *AB* figures the surface of the ground. The part shaded is called the *Parapet* (from the Italian, *para petto*, covering the chest). Its thickness varies according to the weapons at the disposal of the assailant. Its standard height *CD* is 8 feet.

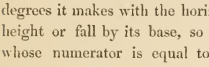
Although it may seem idle to recommend making the parapets of sufficient thickness to resist the projectiles they are exposed to, yet this important subject is sometimes neglected in the hurry of the moment. Nothing more discourages the men entrusted with the defence of a work than to find that they are not efficiently protected. During the Seven Years' War, at the siege of Colberg, a cannon ball came right through the parapet of a battery, and took off the head of a gunner. It is far better to bestow a little more labour to make the parapet too thick, than to fall into the opposite error, for this extra trouble will in the end save time. At the first bombardment of Sebastopol, the French had not calculated on the powerful artillery of the Russians, and in a few hours their batteries and powder magazines were destroyed. Warsaw, in 1832, was defended by earthworks; yet General Paskewich (with a train of 300 guns) soon annihilated the whole.

It was customary to allow 3 feet thickness for musketry, and 1 foot for each pound of shot. Thus 6 feet for 6-pounders, 9 feet for 9-pounders, and so on to 18 feet; but the recent improvements in fire-arms by causing the projectiles of artillery to penetrate more deeply into earth, will necessitate an increase of thickness; but a thickness of 3 feet will still be sufficient to resist the Enfield bullet. The penetration in ordinary soil being ascertained, we obtain that in other materials by multiplying by a co-efficient. (*See* 45).

The parapet should be made at least one-third thicker than the penetration (45).

The *superior slope* DH slants towards the country with an inclination $\frac{1}{6}$, in order to enable the defenders to fire immediately in front, and to see the assailants until they descend into the ditch. It may occasionally slant a little more, but it will have the inconvenience of weakening the crest of the parapet. This slope is also called *plongée*, or *plane of fire*, because it is from it that the fire is poured out. In fortification, instead of measuring the inclination of a slope by the number of degrees it makes with the horizon, or with its base, we obtain it by dividing its height or fall by its base, so that this inclination is represented by a fraction whose numerator is equal to the height, and the denominator to the base.

FIG. 58.



Thus if AB = 1, and BC = 2, the slope AC is said to be at $\frac{1}{2}$; if MN = 3, and NP = 2, the slope MP is at $\frac{2}{3}$. A slope at $\frac{1}{1}$ is often called a slope at 45°. Most military authors on the continent take for the fraction the base divided by the fall; but in reading these fractions no mistake can be made if the fundamental form of a parapet is well understood.

The defenders are posted on the *Banquette* KE. It is level or slightly inclined to the rear, to carry off the water; it is 3 feet wide, or 4 feet 6 inches when destined for two files of men, and stands 4 feet 3 inches below the *crest* of the parapet, this being the most convenient height for a man to fire over and at the same time remain covered. To ascend from the interior of the work, or *Terreplein*, up to the Banquette, a *slope of Banquette* AK at $\frac{1}{2}$ is constructed. A steeper slope would be inconvenient to ascend the banquette, and a more gentle one would occupy too much space inside the work: in fact, this slope is replaced by steps, whenever it is important to economise space.

The parapet is connected with the banquette by the *interior slope* DE at $\frac{3}{4}$, and with the ground on the outside by the *exterior slope* HB at $\frac{1}{1}$.

With an interior slope less steep than $\frac{3}{4}$, the men would be more exposed, especially to pitching fire, and too far from the crest to rest their muskets on the superior slope. A vertical slope would be preferable, but earth would not allow this, and even at $\frac{3}{4}$ it requires (142) artificial means to support it.

The exterior slope in works destined to stand for some time should be made

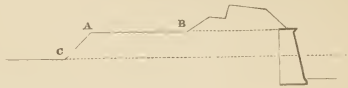
at $\frac{7}{10}$, the slope which earth will generally assume; it corresponds to an angle of 35c.

The intersection of the superior and interior slopes is called the *interior* or *superior* crest, or merely crest, also *line of fire*; that of the superior and exterior slopes is named the *exterior* or *inferior* crest.

This is the shape which experience has taught us to adopt in the field, when we are on level ground, but it should only be considered as a type (154).

In permanent fortifications we find also a *rampart* AB or large mass of earth of various heights, and its *slope of rampart* AC, at $\frac{1}{1}$.

Fig. 59.



This additional height is necessary to protect the buildings, and to command the country.

(52.) *The ditch* is comprised between two slopes; that next to the parapet AB is called the *escarp;* that towards the country CD, the *counterscarp;* the level part BD is the bottom.

Fig. 60.

A ditch may have a triangular profile, such a one is found advantageous when it is without flank defence, because the assailant cannot easily form in it.

The inclination of the scarps varies according to the nature of the soil, from $\frac{1}{1}$ to $\frac{3}{1}$.

	Escarp.	Counterscarp.	Berm.
Strong soil	$\frac{2}{1}$	$\frac{3}{1}$	1 foot
Ordinary soil	$\frac{3}{2}$	$\frac{2}{1}$	2 ,,
Sandy soil	$\frac{1}{1}$	$\frac{1}{1}$	3 ,,

but the escarp, having to support all the covering mass, is always made less steep than the counterscarp; and, to diminish this enormous pressure, a horizontal space AG, called a *Berm*, is reserved at the foot of the exterior slope. This varies from one to three feet, according to the nature of the ground; but it is an inconvenience, and must be avoided when possible, because it affords a resting-place for the assailants, who, after having cleared the ditch, gather in sufficient numbers to give the assault. At the attack of the tête-de-pont of Almaraz, made by the English in the Peninsula (1812), the berms of Fort Napoleon kept off the ends of the scaling-ladders from the parapet: but the first men jumped upon the berm itself, and, drawing up the ladders, planted them there; then, with a second escalade, they won the work.

In permanent fortification these slopes are generally built in masonry, and are either at $\frac{3}{4}$, as in Vauban, or perpendicular, as in the modern system.

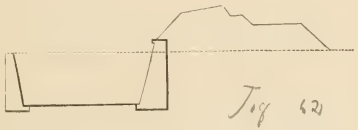


FIG. 62.

When a slope is steeper than $\frac{1}{1}$, earth must be supported by masonry, sandbags, sods, &c. This is called Revetment.

The *depth* of a ditch in field fortification varies from 8 to 12 feet; below 8 feet it would no longer be a serious obstacle; above 12 feet it would become too difficult to excavate.

The *width* is never less than 12 feet, but may extend to 20, or even 25 feet.

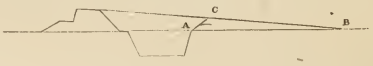
In permanent works the depth may average 30 feet, and even more, and the width 90 feet and upwards.

It is a principle that is constantly adhered to, especially in the field, that the ditch must furnish all the earth necessary for the covering mass. Therefore, when the thickness of the parapet has been once determined upon, one may assume the depth of the ditch (8 feet or 12 feet), and calculate the width, or assume the width (never less than 12 feet), and calculate the depth. This operation is called the calculation of *deblai* (ditch), and *remblai* (mass).

(53). The critical moment for the assailant is the instant when he arrives at the counterscarp of the ditch, because he hesitates to cross it, and is there exposed

to a murderous fire; but if the parapet is small, and the ditch narrow, the superior slope produced meets the ground too far, and a man might stand safely at A. To obviate this the ground is raised as in CB, and this double slope is called a *glacis*. The crest of the glacis should be at least 4 feet below the superior crest, as it would otherwise enable the assailant to fire into the interior of the work.

Fig. 63.



(54). Finally, to complete the work, a little path, called a *covered way*, is sometimes reserved between the counterscarp and the glacis.

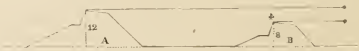
Fig. 64

It is rarely employed in field fortification, because it implies too large a garrison for the defence, but it is constantly found in permanent fortification (335).

The two component parts of all fortification are the parapet and the ditch; in its most complicated state we find the rampart, parapet, ditch, glacis and covered way.

(55). The height of the parapet above ground is called *command*, and the height above the bottom of the ditch is the *relief*. The difference of command of two works is called *command of fire*, thus we say that work A has a command of 4 feet over work B.

Fig. 65.



If the command is only sufficient to permit the defenders of a work to look over the other it is named *command of observation*.

The standard height of a work is 8 feet or 7 feet 6 inches on level ground, in order to give cover against the fire of men on horseback. In some special cases,

such as when it is necessary to get cover from the views of commanding heights, it may be raised to 10 and even 12 feet, whilst at other times it may be lowered to 7 feet, 6 feet, and even to $4\frac{1}{2}$ feet when there is occasion for great haste.

When the command is small, the fortification is said to be *rasant*, when great we call it *fichant*.

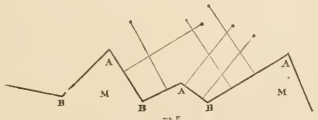
The name of *breastwork* is given to those parapets hastily thrown up, the command of which is so small ($4\frac{1}{2}$ feet) as to require no banquette.

SECTION II.—Outline.

(56.) A parapet and a ditch that would stretch along the ground in a straight line would not completely answer the purpose in view, since the defenders could only oppose a direct fire to a superior one, and this defence would cease as soon as the assailant was in the ditch.

It is necessary to construct the work according to a crooked line, offering *salient*, AAA, and *re-entering* angles BBB. By this disposition the assailant is exposed to fire in several directions, and he will be compelled to abstain from attacking the re-entering angles in order to direct his efforts on the salients, where he is less exposed. The defenders give thus a superiority to their musketry, and can concentrate their means of resistance where they are likely to be attacked.

Fig. 66.



The parapet and ditch being thus constructed along faces, enclose a space M, and form what is called an *intrenchment*.*

The combination of these angles, and the general configuration of the work on the ground, constitute what is called the *outline* or *trace*.

This outline will vary indefinitely, and it is in its judicious selection that an officer will display his skill, it being borne in mind that fortification must make the best of the ground.

* An *Epaulment* differs from an Intrenchment by the absence of the banquette and its slope. It is constructed to protect artillery, or occasionally to shelter from the views of the enemy, troops of cavalry and infantry.

The interior ground of a work M is called its *terreplein;* the same name applies to the nearly level space between the parapet and the slope of the rampart.

(57.) To understand the properties of angles, it must be observed that a soldier behind a parapet is expected to fire straight before him, and that unless he is expressly ordered to do so, he must not fire in an oblique direction. This rule is most essential. It often happens that troops are called upon to occupy and defend a series of works, the outline of which is calculated to answer a combination of defence. The flanking of a ditch or of a face *must* take place: it is a sacred duty, and a garrison must even sacrifice its safety to fulfil it, just as a rear-guard or an outpost must sometimes devote itself for the safety of the army.

If, then, we consider a salient angle, the shots of the last man on each face leave a space totally *undefended.* This space is called *undefended sector* or *undefended angle.* This is an inconvenience common to all salient angles, and is another reason which will induce the assailant to select the salient as the point of attack.

The smaller the angle, the larger will be this undefended space; besides, with a very acute angle, the parapets of both faces would meet on a narrow ridge,

Fig. 67.

Fig. 68

and be unable to resist the fire of the enemy's artillery, or even heavy rains; and the interior space would become so limited that no room would be left for a gun in the capital, (the line that bisects a salient angle is called in Fortification its *Capital,*) as is often done, to fire on the advancing columns of attack.

For these reasons the salient angles must never be less than 60°.

It might be asked why it is precisely 60° and not 55° or 65°, &c. It is because the capital may receive oblique fire, in cases of necessity: as a *man cannot oblique* more than 60°, it follows, that if the angle were smaller than 60°, the capital could not be defended even by oblique fire.

Fig. 69.

(58.) The sides of a re-entering angle according to the direction of which a face is flanked, are called *lines of defence.* Such are AB, AC.

If the face that is flanked is not contiguous to the flanking one, the line AC, is still called line of defence. The angle B A C, is in both cases called *angle of defence.*

Fig. 70.

Fig. 71.

Should the angle be small, the men would fire on their own party; and if it were very large, the flanking could not be effected except by an oblique fire. Therefore, limits have been fixed at from 90° to 120° for these angles.

Fig. 72.

As the superior slope of parapet is inclined at $\frac{1}{6}$, the shot that follows the line AB, meets the ground at a distance CD from the crest, equal to six times the command; and if the parapet belongs to the face of a re-entering angle, the defenders cannot see the ditch before them for a distance MN, equal to six times the relief.

Fig. 73.

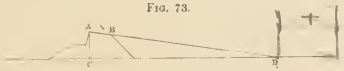
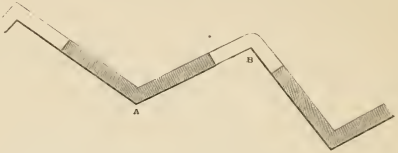


Fig. 74.

This space which cannot be seen by the defenders, is called *dead angle*. It is a serious inconvenience of the re-entering angles. With the ordinary relief of field works, the distance CD is about 15 yards, that of MN 30 yards.

(59.) Salients are points of attack: we obviate the inconvenience of the undefended space which they necessarily present, by artillery in the capital, by accessory means, and, above all, by flanking. The critical moment is when the enemy arrives at the counterscarp and descends into the ditch; should he then be unexposed, he may mine the work, or collect in sufficient force to assault it vigorously. We have seen that along every flanked face, AB, there is a dead

FIG. 75.



angle occupying nearly 30 yards; if the faces then are shorter than 30 yards, no part of the ditch is seen by the defenders. As, however, the enemy in reaching the salient *B* must be seen in the ditch, we are obliged to make the faces longer than 30 yards.

The inferior limit of faces destined to flank each other, has sometimes been fixed at 15 yards, but this dimension only permits a sight of the top of the counterscarp in front of the salient, and the whole ditch is dead. It should not, therefore, be adopted for works from which a vigorous defence is expected.

As for flanks, or lines of parapet intended to give a flank fire on the side of a work, they may be made as short as convenient.

The maximum length of the faces of a re-entering angle, or what is the same, of lines of defence, had been fixed at 180 yards, because the fire of the old musket was too uncertain beyond that range. The introduction of the Enfield rifle, will permit an increase of that distance, but it will not produce a great alteration in the faces of field works, because there is seldom any occasion to make them longer than 100 yards. In some cases, however, it may enable us advantageously to modify the outline, as we shall see.

(60.) The fundamental principles of all fortification which we now recapitulate, have been deduced from the nature of the arms employed, and are rendered evident by the most simple considerations.

The extent of a work must be proportioned to the number of men intended for its defence.

The outline must give as much direct and flanking fire to bear on the point of attack as possible.

The salient angles must never be less than 60°.

The angle of defence must be between 90° and 120°.

The length of the lines of defence should not be less than 30 yards, and should not exceed the range of musketry. (*See* 435.)

A work in which all these conditions are observed is called a good work; but here theory must give way to practice: the ground to be fortified is given, and we must make the best of the foregoing principles; but it is not always possible to apply them all at the same time. Although in theory a work without flanking is deficient, yet the conformation of the ground and the destination of the work may be such, that this consideration becomes of less importance, and the work may be nevertheless a good one.

CHAPTER III.

ON THE DRAWING OF FORTIFICATION.

SECTION I.—Scales.

(61.) The representation of a work of Fortification can be made of different sizes according to the end in view, it being clear that the greater the accuracy required, the larger the drawing should be.

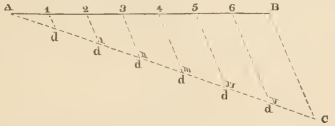
The length of a dimension of the drawing, compared with that of the corresponding dimension of the work on the ground, is called the scale of the drawing. Thus, if a face eighty yards in length, occupies but one inch in the drawing, the scale is that of one inch to eighty yards. Again, if a wall a hundred yards long is represented by a line of 5 inches, the scale is that of 5 inches to 100 yards, or of one inch to 20 yards. As one inch represents 20 yards, or $20 \times 36 = 720$ inches, we may say that every length on the ground is represented in the drawing by a dimension 720 times smaller, and that the scale is of $\frac{1}{720}$. These two methods of expressing the scale are identical, and we may adopt one or the other. A scale of $\frac{1}{63\,360}$, signifying that the dimensions on paper are 63,360 times less than their corresponding ones, on the ground, it follows that one inch represents 63,360 inches, and that the scale is of one inch to 63,360 inches or one mile.

Supposing that a drawing is to be made on the scale of $\frac{1}{720}$. If we draw a line 5 inches long, and divide it into 10 equal parts, it is clear that each part will represent 10 yards, since 5 inches stand for 100 yards. If we further sub-divide each part into ten, the new subdivisions will each represent one yard. A line, thus sub-divided, is called the scale of the drawing, and we can by means of a pair of compasses, obviously use it on paper, as we would on the ground use a chain or any other instrument.

To construct that scale properly, draw in pencil three parallel lines, about $\frac{1}{10}$ of an inch apart, and mark off on the bottom line five inches. Divide that length

into ten equal parts, and the left-hand division into ten parts again. To divide a line AB, into a given number of equal parts, draw through the extremity A a line AC, making with AB any angle; on AC mark off any length A d, and take as many parts A d = dd' = d'd'' as there are divisions to be made on A B. Join the last point C with B, and through d', d'', d''', &c., draw parallels to B C. these parallels intersect A B in points 1, 2, 3, 4, &c., equally distant. Through

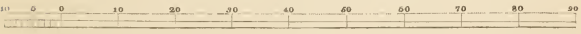
Fig. 76.



all these points of division, draw perpendiculars to the parallel lines, limiting those that mark the primary divisions by the top line, and those of the secondary divisions by the middle line. The perpendicular corresponding to the 5th or middle subdivision, may be carried half way between the two upper parallels. In inking the scale omit the top line, and draw the lower one thick. In order to

Fig. 77.

Scale of $\frac{1}{720}$.



make this scale convenient for taking off distances, we mark 0 at the point where the primary and secondary divisions meet, and we number successively 10, 20, 30, &c., from left to right. The secondary divisions are numbered 5 and 10. The unit of measure, "yards" in this example is written at the right, and the name of the scale, either scale of $\frac{1}{720}$, or scale of one inch to 20 yards, is written above it.

The method of using this scale is very simple. Suppose we want to take off 36 yards; place one point of the compasses on the primary division marked 30, and the other point on the 6th sub-division, the length included between the two points will be 36 yards. Conversely, to value a dimension of the drawing, take it with the compasses, by placing one point on the division 0, and reading the figure corresponding to the right point. If this point does not coincide with a primary division, move the compasses to the left, until the right point corresponds with the nearest division, the left point of the instrument will then mark the required sub-division.

As the theory of scales should be thoroughly understood before any attempt to draw a fortification is made, we shall give a few examples to render the subject familiar.

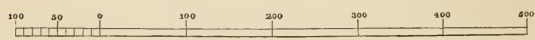
I.—To draw a scale in which 360 yards are represented by 2·7 inches.

The length of a scale varies generally between 4 and 6 inches, and since the number of units which it represents should always be a simple multiple of 10, 100, 1000, &c., simple for the sake of convenient divisions, let us assume that the scale represents 600 yards. From the proportion 360 : 2·7 :: 600 : x, we find that 600 yards will be represented by $\frac{600 \times 2{\cdot}7}{360} = 4{\cdot}5$ inches.

Draw therefore, as above, three parallel lines, and take on the lower one a length

FIG. 78.

Scale of $\frac{1}{4800}$.



of 4·5 inches, which will represent our 600 yards ; divide it into six equal parts, each of which will represent 100 yards; sub-divide the left hand part into ten, each of the sub-divisions denotes 10 yards. These secondary parts are too small to be further sub-divided, the scale cannot, therefore, show parts less than 10 yards ; but if it were necessary to mark off single yards, we should have recourse to a method which we shall hereafter point out. (*See* 62.)

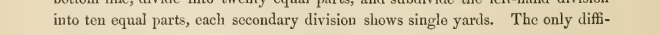
The figuring of this scale is done exactly as in the former example. As for the representative fraction, we observe that 360 yards or 12,960 inches are represented by 2·7 inches ; the proportion between a dimension of the drawing and the actual size, is 2·7 : 12,960 or 27 : 129,600. Therefore the representative fraction is $\frac{2{\cdot}7}{12960}$ or $\frac{1}{4800}$.

II.—To construct a scale of $\frac{1}{1260}$, to measure yards.

In this case, 6 inches representing 6×1260, or 7560 inches $= 210$ yards, we shall have a scale of convenient length if we represent 200 yards. As 200 yards or 7200 inches are represented by $\frac{7200}{1260} = 5{\cdot}71$ inches, set off 5·71 inches on the bottom line, divide into twenty equal parts, and subdivide the left-hand division into ten equal parts, each secondary division shows single yards. The only diffi-

FIG. 79.

Scale of $\frac{1}{1260}$.



culty is to draw with sufficient accuracy 5·71 inches. Now 5·71 inches is the same as $5\frac{71}{100}$ or $\frac{571}{100}$ inches, or, dividing numerator and denominator by 2, the same as

285½ fiftieths of an inch. If we have therefore a scale on which are found fiftieths of an inch, it is easy to take off that length as well as any other expressed in hundredths of an inch. Such divisions of fiftieths of an inch are usually found on protractors, or Marquois scales (64).

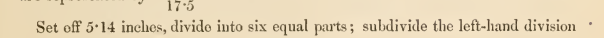
III.—To construct a scale for a drawing in which we find that $1\frac{1}{2}$ inches represent 17·5 feet.

Take 60 feet as the whole length of the scale; 17·5 : 1·5 : : 60 : x, then 60 feet are represented by $\frac{1{\cdot}5 \times 60}{17{\cdot}5} = 5{\cdot}14$ inches.

Set off 5·14 inches, divide into six equal parts; subdivide the left-hand division

FIG. 80.

Scale of $\frac{1}{140}$.



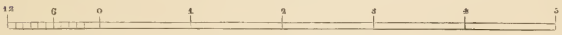
into ten: the secondary divisions will show single feet. As 17·5 feet = 210 inches, the representative fraction is $\frac{1{\cdot}5}{210} = \frac{1}{140}$

IV.—To draw a scale of $\frac{1}{15}$ to measure feet and inches.

Assume 6 feet as the whole length: these will be represented by $\frac{6 \times 12}{15} = \frac{72}{15}$ = 4·8 inches ($= 4\frac{8}{10}$). Set off 4·8 inches, divide into six equal parts; the divisions mark single feet. Subdivide one part into twelve, and we obtain inches.

FIG. 81.

Scale of $\frac{1}{15}$.



V.—To draw a scale of 8 inches to 1 mile, to measure yards. Since 8 inches represent 1760 yards, 4 inches stand for 880 yards, and we shall have a convenient length by assuming 1000 yards. Now, 1760 : 8 :: 1000 : x, therefore 1000 yards are represented by $\frac{8 \times 1000}{1760} = 4{\cdot}54$ inches $= \frac{227}{50}$ inches.

Dividing this length into ten equal parts, and subdividing one of them into

FIG. 82.

Scale of $\frac{1}{7920}$, *or* 8 *inches to* 1 *mile.*

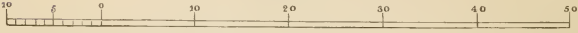
ten, the secondary divisions show 10 yards. Smaller parts cannot be shown (see 63). The representative fraction is $\frac{8}{8 \times 3 \times 6 \times 0} = \frac{1}{7 \times 9 \times 0}$.

VI. In a French drawing we find a scale of French metres in which 70 metres measure 6·3 English inches. Construct a scale of English yards for that drawing, 1 metre being equal to 3·270 English feet. 70 metres $= 70 \times 3{\cdot}27$ English feet $= \frac{70 \times 3{\cdot}27}{3} = 76{\cdot}3$ yards, which we find represented by 6·3 inches. Putting $76{\cdot}3 : 6{\cdot}3 :: 60 : x$, we find that 60 yards are represented by $\frac{6{\cdot}3 \times 60}{76{\cdot}3} = 4{\cdot}95$ inches.

This length divided into six equal parts, shows parts of 10 yards, which

FIG. 83.

Scale of $\frac{1}{436}$.



subdivided into ten gives single yards. As 70 metres $= 228{\cdot}9$ English feet $=$ 2746·8 inches, the representative fraction will be $\frac{6{\cdot}3}{2746{\cdot}3} = \frac{63}{27468} = \frac{1}{436}$

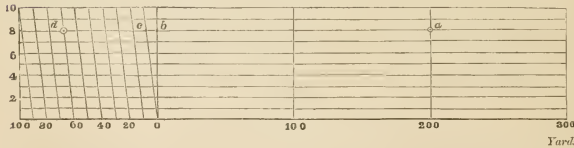
(62). When a scale is required to show minute lengths, the former method is no longer available, and we have recourse to *diagonal scales*, the construction of which will be explained by one or two examples.

I. To draw a scale of $\frac{1}{3000}$ to show single yards.

Assume a length of 400 yards: it will be represented by $\frac{400 \times 36}{3000} = 4{\cdot}8$ in. Draw a line 4·8 inches long, divide it into four equal parts; subdivide the left-hand part into ten; then each subdivision shows 10 yards. Figure the scale as an ordinary one, 100, 80, 60, 40, 20, 0, 100, 200, 300. Parallel to it draw ten

FIG. 84.

Scale of $\frac{1}{3000}$.



parallel and equidistant lines about $\frac{1}{10}$ of an inch apart. Through the points of primary division, 100, 0, 100, 200, 300, draw perpendiculars intersecting the ten parallels, and number the left-hand perpendicular as in the diagram. Join

the last point 10 to subdivision 90, and through subdivisions 80, 70, 60, &c., draw parallels to 10-90, crossing the former ones diagonally. The scale is now complete.

The diagonal lines, being parallel to one another, intercept segments of 10 yards on the other parallels; but between the perpendicular and the diagonal 0 the intercepted segments are of different lengths; and from a well known principle of geometry, the part intercepted on the first parallel is $\frac{1}{10}$ of a subdivision, and represents therefore one yard; on the second parallel it is $\frac{2}{10}$, on the third $\frac{3}{10}$, and so on, the figures written on the left hand perpendicular indicating the number of yards intercepted.

To show how to use this scale: suppose it is required to take off 268 yards. Place one point of the compasses on the intersection of the parallel numbered 8 and the perpendicular 200, and put the other point on the intersection of the same parallel with diagonal 60. The legs of the compasses will thus include 268 yards, viz., 200 from *a* to *b*, 8 from *b* to *c*, and 60 from *c* to *d*.

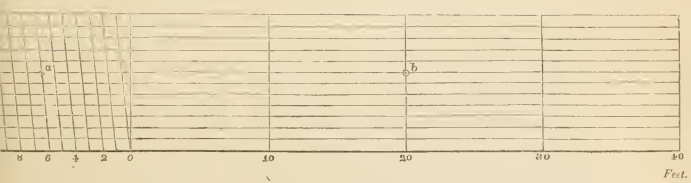
II. To draw a scale of $\frac{1}{100}$ to show feet and inches.

Assume 50 feet. This is represented by $\frac{50 \times 12}{100} = 6$ inches.

Draw a line of six inches, divide it into five equal parts; the last part subdivided into ten will show single feet. Figure the line 10, 8, 6, 4, 2, 0, 10, 20, 30, 40. In order to show inches, we must divide the foot into 12 equal

FIG. 85.

Scale of $\frac{1}{100}$.



parts. Draw, therefore, 12 equidistant lines parallel to the first: through the points 10, 0, 10, 20, 30, and 40, erect perpendiculars; number the left-hand perpendicular, 2, 4, 6, 8, 10 and 12. Draw the diagonal 12 — 9, and parallels to it, as in the former example. It is readily seen that to measure 26 feet 7 inches, for instance, the compasses must include the distance *a b*.

The selection of the scale on which a drawing is to be made is not altogether arbitrary, for it depends on the one hand upon the dimensions of the paper, and

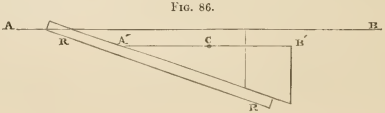
on the other upon the degree of accuracy required in the representation of the work. When we have to represent a work 250 yards long, it is evident that if our sheet of paper is only 8 inches long, we cannot employ a scale larger than 8 inches to 250 yards. Any scale smaller than this would, on the contrary, enable us to represent the entire work. Still, if we were to employ a very small scale, we should fall into a serious difficulty, because small details could not possibly be represented. The accuracy required must therefore be our guide. In the scale of 1 inch to a mile, for instance, a face of 10 yards would be represented by $\frac{1}{176}$ of an inch, a dimension far too small to be appreciated or represented. If it were, however, necessary to represent everything within ten yards, which scale should we select? To answer this, let it be observed, that in supposing a drawing mathematically correct, we unavoidably commit, in reading it, an error due to the imperfection of our sight. We cannot appreciate a dimension less than $\frac{1}{100}$ of an inch, because our eyes cannot distinguish whether the points of the compasses are within $\frac{1}{100}$ of an inch too near, or too far apart. This uncertainty in reading amounts to $\frac{1760}{100} = 17$ yards, in the scale of one inch to a mile. If the drawing must enable us to appreciate 10 yards, the scale should be such that $\frac{1}{100}$ of an inch does not represent more than 10 yards; therefore the scale must not be less than 1 inch to 1000 yards.

For the same reason, the scale in which a drawing is made shows at once with what degree of exactitude it may be read. In the scale of 4 miles to an inch, the smallest distance we can possibly measure is $\frac{4 \times 1760}{100} = 70$ yards.

We have taken for granted that $\frac{1}{100}$ of an inch is the smallest dimension which we can appreciate, although divisions of an inch into 600 parts have been obtained. In drawing, however, such accuracy becomes an illusion, inasmuch as the paper on which we draw contracts and expands under the influence of heat and moisture, and $\frac{1}{100}$ of an inch is already very small.

(64). An excellent selection of scales is found in the instruments called "*Marquois Scales*," which consist of a right-angled triangle and two flat rulers of wood. These instruments are very handy for drawing parallels and perpendiculars with. If it is required to draw through point C a parallel to A B, place the bevelled edge of the triangle on A B, apply a ruler R R to the hypothenuse, and

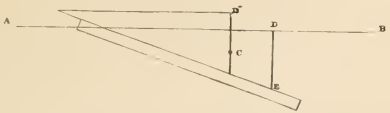
FIG. 86.



press it down with the left hand to steady it; slide the triangle with the right hand till the edge passes through C, when A′ B′ will be parallel to A B.

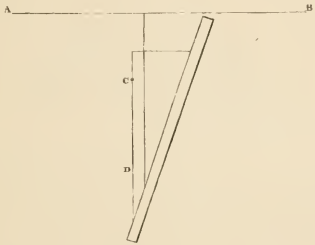
If a perpendicular has to be drawn to A B through a point C, place the bevelled edge of the triangle on A B, apply the ruler as before, and slide the

Fig. 87.



triangle till the small side D E passes through C, when C D′ will be perpendicular to A B. Instead of applying the bevelled edge on A B, the small side might be placed on it, and the triangle slided till the bevelled edge passed through C.

Fig. 88.



These two operations can, however, be made with any triangle and any ruler. What distinguishes the Marquois instrument, and renders it especially useful for drawing fortification with, is that it is so constructed as to enable us to draw parallels at any required distance without the help of compasses. For this purpose, the triangle has its longest side precisely equal to three times its smallest, and is marked with an index on its middle.

The rulers, one foot long, have two scales on each edge; an ordinary scale a little inside the edge, and an artificial scale on the edge itself: the divisions of the artificial scale are made exactly three times as long as those of the ordinary or natural scale, and are exclusively intended to be used in sliding the triangle. The graduations of this outer scale extend both ways from the centre.

If we have to draw a line parallel to A B, and at 40 feet, for instance, from it, select the ruler that carries the natural scale employed for the drawing, and proceed as in the former problem. Place the bevelled edge of the triangle on A B, and adjust the ruler so that an exact division of the artificial scale coincides with the index *o*. Slide the triangle until the index has moved from *o* to *o′* along

Fig. 89.

forty divisions. The line A′ C′ will be parallel to A C, and at 40 feet from it. This is easily proved from the similitude of the triangles A C H, A P H′. Since A H = 3 C H, therefore A H′ = 3 P H′, but A H′ = A H + H H′ = A H + *o o′*, therefore A H + *o o′* = 3 P H′ = 3 (C′H′ + C′P) = 3 (C H + C′P) and substracting from both sides the equals A H and 3 C H, there remains *o o′* = 3 C′P. The artificial scale being three times larger than the natural, it follows that C′P is precisely equal to the distance required.

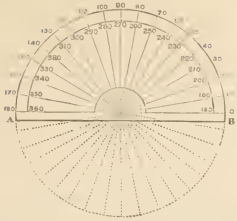
In the scale marked 50, we find that each subdivision represents $\frac{1}{50}$ of an inch, and we employ it, as stated above, (61. II.) to measure lengths expressed in hundredths of an inch. In example 3, we had to set off 5·14 inches or $\frac{514}{100} = \frac{257}{50}$ inches. Placing one point of the compasses on division 25 of the 50 scale, and the other point on subdivision 7, we have the required length.

The Marquois scales usually contain the scales 20, 25, 30, 35, 40, 45, 50, and 60. Taking one of the subdivisions to represent one yard, the scale $20 = \frac{1}{720}$; $25 = \frac{1}{900}$; $30 = \frac{1}{1080}$; $35 = \frac{1}{1260}$; $40 = \frac{1}{1440}$; $45 = \frac{1}{1620}$; $50 = \frac{1}{1800}$; $60 = \frac{1}{2160}$.

If one subdivision represents one foot, the scale $20 = \frac{1}{240}$; $25 \frac{1}{300}$; $30 = \frac{1}{360}$; $35 = \frac{1}{420}$; $40 = \frac{1}{480}$; $45 = \frac{1}{540}$; $50 = \frac{1}{600}$; $60 = \frac{1}{720}$. Again, taking one of the primary divisions for one yard, we should have the scale $20 = \frac{1}{72}$; $25 = \frac{1}{90}$; $30 = \frac{1}{108}$, &c.

(65). A *protractor* generally consists of a semicircle of thin transparent horn. It is, however, occasionally made of brass. Its circumference is subdivided into degrees or half degrees, and its graduations on the outer arc extend from right to left from 0° to 180, whilst on the inner arc, corresponding to the rest of the

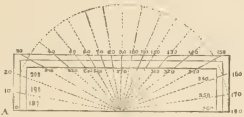
Fig. 90.



circumference, the graduations from right to left run from 180° to 360°. The margin A B is parallel to the diameter 180—0.

The instrument is frequently made of a rectangular piece of ivory, divided

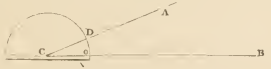
Fig. 91.



and graduated from left to right, as in the diagram, the margin coinciding with the diameter 0—180.

Whatever be its form, this instrument is employed to measure the angles of a drawing or to construct (protract) the angles we require. To measure the angle formed by two given lines A C, C B: place the centre of the protractor on the

Fig. 92.

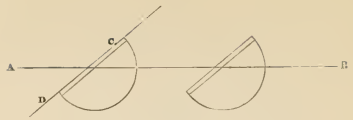


vertex C, and the radius *o*, on one side C B, the other side will indicate in D the value of the angle.

To draw through a point C, a line inclined to C B at a given number of degrees: place the centre of the protractor on C (fig. 93), the radius *o* coinciding with C B, make a dot D at the graduation required, and draw C D.

If the point given is not in the line, place the radius marking the number of degrees required on the given line A B, and slide the protractor along that line

Fig. 93.



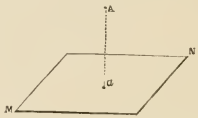
until the margin passes through C, keeping the radius carefully on A B; and draw C D.

SECTION II.—Projections.

A work of Fortification is bounded by a certain number of surfaces, whose intersections are lines. To represent a work, we must, therefore, find a means of constructing a drawing, which will show these lines of intersection in their relative positions. As a line may be considered as composed of a series of points, the first step that must be taken is the representation of points. This is done by projections on planes.

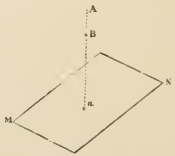
(66). The *projection* of a point on a plane is the foot of the perpendicular drawn from that point to the plane. Thus, if A be a given point in the space, and

Fig. 94.



M N any plane, the perpendicular A *a* meets the plane in *a*: and this point *a* is called the projection of A on plane M N. But it is obvious that any point of the line A *a*, B for instance, will have for its projection on the plane M N the same

Fig. 95.



point *a*; therefore, one projection on a fixed plane is not sufficient to represent a

given point: all we can conclude from it is, that the point is situated somewhere in the line perpendicular to the plane through *a*.

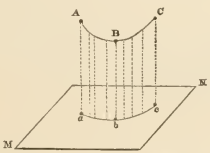
Suppose now a second plane N P standing anywhere at right angles to M N, if

Fig. 96.

A a' be drawn perpendicular to it, a' will be the projection of A on that plane, and, as before, we know that A must be somewhere in the perpendicular to N P drawn through a'. The projections, a, a', on two fixed planes, will determine precisely the position of A, since the two perpendiculars erected through a, a' can meet only in one point. It is found most convenient to take for planes of projections a horizontal and a vertical one; the projection on the horizontal plane is called *plan*, that on the vertical is called *elevation*. If M N is horizontal, N P vertical, a is the plan, a' the elevation of A, and the line N O, in which the planes of projection intersect, is called the *ground line*.

The projection of a line on a plane is obtained by projecting every point; thus, if from the points A, B, C, &c., of the curve A B C perpendiculars

Fig. 97.



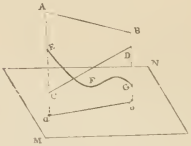
A *a*, B *b*, C *c*, &c., are let fall on the plane M N, the line *a b c* is the projection of A B C, and if M N be horizontal, *a b c* is the plan of A B C. As the projection of a straight line is also a straight line, if we only

Fig. 98.

project the points A and B, in a and b, and join $a\ b$, we obtain at once the projection.

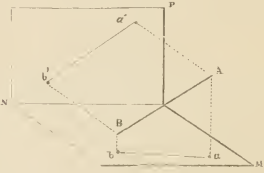
One projection is not sufficient to determine the position of a line. If we take C and D on the perpendicular A a and B b, the line C D will have also $a\ b$ for projection; any curve E F G, situated in the vertical plane A a B b, will

Fig. 99.



have likewise $a\ b$ for projection. We must, therefore, as we have seen for one point, adopt two planes of projection. If M N be horizontal and N P vertical, the *plan* $a\ b$ and the *elevation* $a'\ b'$ perfectly determine the position of A B, since

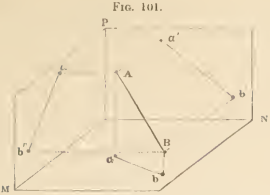
Fig. 100.



it is the intersection of the planes a A b B perpendicular to M N and a' A b' B, perpendicular to P N, which planes can have but one intersection.

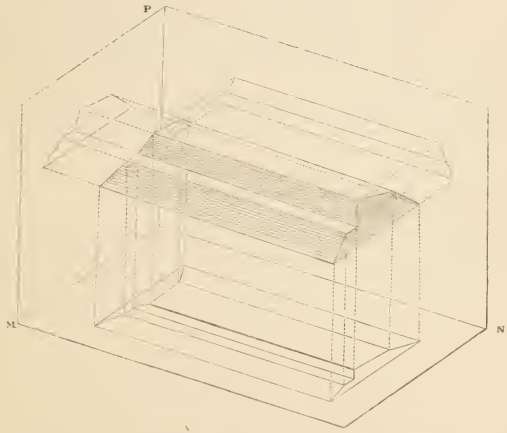
Whatever may be the position of the horizontal plane of projection, the plan will invariably be the same, but the elevation will vary with each position of the vertical plane. Nevertheless, the elevation on any vertical plane, together with the plan, will perfectly determine the line. In the annexed diagram, for instance, the plan $a\ b$ and elevation $a'\ b'$ represent A B, but $a\ b$ and $a''\ b''$ represent it as well.

Fig. 101.



A work of Fortification is bounded by seven planes, the slope of banquette, the banquette, the interior slope, the superior slope, the exterior slope and the two limiting slopes. These slopes intersect in 18 straight lines, which meet one another in 12 points. The projections of these 12 points, properly joined, give the projection of the whole work. Imagine a horizontal plane M N situated

Fig. 102.

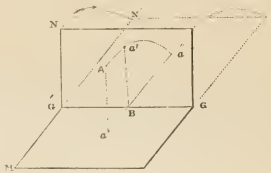


beneath the parapet, and two vertical planes N P, M P beside it; from the 12 points draw perpendiculars to the three planes, and join their projections as they are in the work; and we thus obtain a plan and two elevations.

Before showing the relation between the plan and an elevation, let us see how this method of projections can be applied to drawing on a flat sheet of paper.

Let A be a given point, a its plan on M G, and a' its elevation on any vertical

Fig. 103.



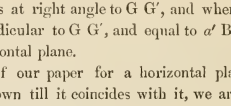
plane N G, the ground line being G G'. If from a and a' perpendiculars a B, a' B are drawn to the ground line, it is obvious that they will meet that line in the same point B, so that a A a' B forms a rectangular parallelogram; and, therefore, A a = a' B, A a' = a B. Imagine now the vertical plane turned about the ground line G G as an axis, in the direction N N', until it coincides with plane M G'.

The line a' B remains at right angle to G G', and when a' has come to a'', the line a'' B is still perpendicular to G G', and equal to a' B, or a A, the height of point A above the horizontal plane.

Taking the surface of our paper for a horizontal plane, and supposing the vertical plane turned down till it coincides with it, we are enabled to construct both plan and elevation on our sheet.

Let G G' be our ground line or intersection of the vertical and horizontal planes, and a the plan of a point: the point itself lies somewhere in a vertical line, passing through a, and its elevation must be somewhere on the perpendicular

Fig. 104.



drawn from a to the ground line, at a distance from B equal to its height above its plan. If, then, a and a' are the plan and elevation of a given point, we know that it lies vertically above a at a distance equal to B a'.

Again, if $a\,b$ and $a'\,b'$ be the plan and elevation of a straight line A B, we see that the extremity A lies vertically above a, at a distance $m\,a'$, and that B

Fig. 105.

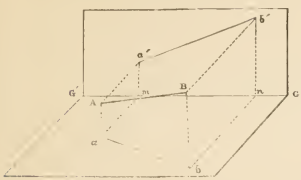
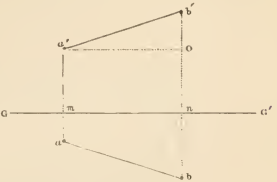


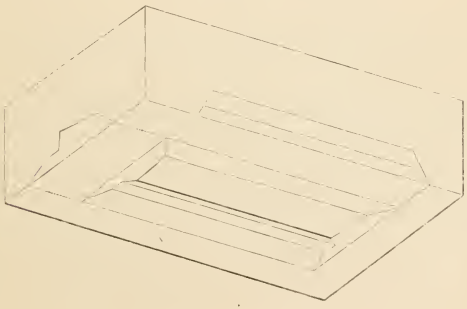
Fig. 106.



is vertically above b, at a distance $n\,b'$, so that B is higher than A by $n\,b' - m\,a' = o\,b'$, whilst $a\,b$ is the distance from A to B, measured horizontally. A *plan*, therefore, gives us the horizontal distances, and an *elevation* the vertical distances between any two points; hence, we can fully fix the position of points, and consequently of lines and surfaces.

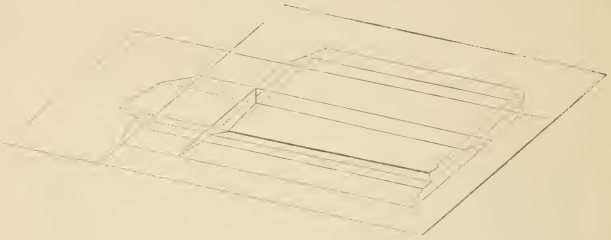
We have said that the plan is invariably the same, whatever be the position of the horizontal plane of projection: in the example of a parapet, imagine now the work resting on the horizontal plane itself, the plan is not altered, and the elevations remain the same as they were; but their bottom lines coincide with the ground lines.

Fig. 107.



The vertical planes being now turned until they coincide with the horizontal one, we have the elevations and plan represented on the same sheet, the ground lines indicating the positions of the vertical planes, and the elevation of any point being still on the perpendicular, drawn from its plan to the ground line.

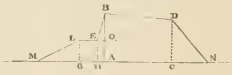
FIG. 108.



(67.) These principles once understood, we can proceed with the drawing of a few elementary examples of Fortification. Let us, for the first step, draw the plan of a parapet 12 feet thick, 8 feet high, and 20 yards long.

In order to ascertain the true horizontal distance between every line of this parapet, let us draw M N to represent the level of the ground; and erect a per-

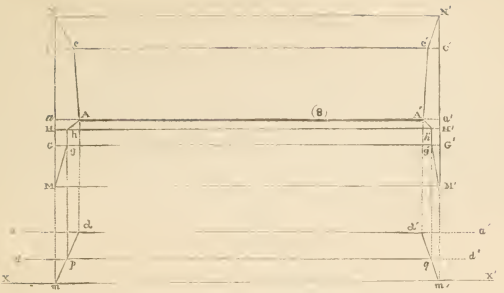
FIG. 109.



pendicular A B = 8 feet, take A C = 12 feet, draw the perpendicular C D = A B — $\frac{AC}{6}$ = 6 feet, and join B D; take C N = C D and join D N; parallel to M N and 4·25 feet below B, draw a line L O; from O to E carry the third of 4·25 = 1·4 and join E B; draw the perpendicular E H, and a parallel L G to it, at a distance of 3 feet or 4·50, according as the banquette is intended for one rank or two; making G M = 2 G L = 7·5 and joining M L, we have completed the profile (51,69), and we have in M G, G N, H A, A C, C N, the horizontal distances between each line of our Fortification.

If now we make A A′ = 20 yards, represent the sub-crest (or projection of the

Fig. 110.



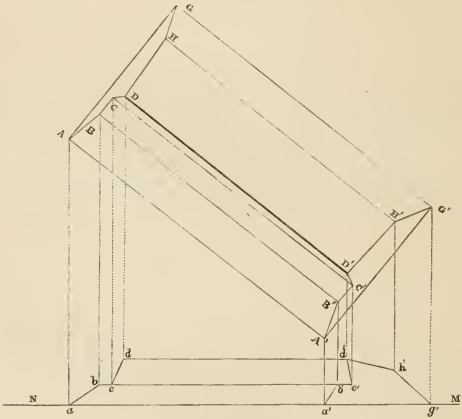
line of fire), and draw parallels to it at the respective distances $a\,H = 1{\cdot}4$, $H\,G = 3$, $G\,M = 7{\cdot}5$, $a\,C = 12$, and $C\,N = 6$, these lines will be the projections N N′ of the foot of the exterior slope, C C′ of the exterior crest, H H′ of the foot of the interior slope, G G′ of the top, and M M′ of the foot of the slope of banquette. There remains now to be constructed the slopes that limit the parapet at both extremities. Suppose that they slant at $\frac{3}{1}$: produce A A′ of $A\,a =$ half the command $= 4$ feet, and through a draw M N perpendicular to a A; take $G\,g = \frac{1}{2}$ the height of the banquette $= \frac{3{\cdot}75}{2} = H\,h = G\,g$; $C\,c = \frac{1}{2}$ the height of the exterior crest, and join M g, g h, h A, H c, c N. If the slope had been at $\frac{3}{4}$ as in the right extremity of this parapet, the line M′ N′ would be drawn at $\frac{1}{2}$ of the command from A′, and the other dimensions would also be a third instead of a half.

The plan of the parapet is now complete, and we see that the length and position of the superior crest being given, together with the thickness of the parapet, the whole figure is readily constructed. A plan constructed in a scale would be sufficient alone to enable us to execute the work, since the distance A C is equal to the thickness of the parapet, and C N to the command, minus a sixth part of this thickness, everything in fact being known, yet it is usual to write the command near the suberest as we have done in this example. Elevations serve to give an idea of the relative heights of the various parts of a work at a glance.

(68.) Suppose now that an elevation of this parapet is to be made on a vertical plane, whose ground line is X X. As an elevation, shows the true vertical distances, if we draw $a\,a'$ parallel to and 8 feet above X X, it will be the elevation

of the crest, (Fig. 110), another parallel $d\,d'$ at 3·75 above X X, will be the elevation of the foot of the interior slope, and of the top of the slope of banquette, since both lines are at the same level, and X X itself will represent the foot of the slope of banquette. As the elevation of any point lies in the perpendicular drawn from its plan to the ground line, the elevations of M, M, are found in m, m', those of h, g, and h', g', in p and q, and lastly, the elevations of A and A′ in a, a'; the lines $a\,m$, $a'\,m'$ being in our example the elevations of the limiting slopes. We do not represent the exterior crest because it is lower than A A′ and cannot be seen through the parapet. It is evident that the distance between the ground line and the plan, or in other words, the distance of the vertical plane of projection from the work, has no influence whatever on the elevation; but an alteration in the direction of that vertical plane at once changes the elevation. Let us take M N

Fig. 111.

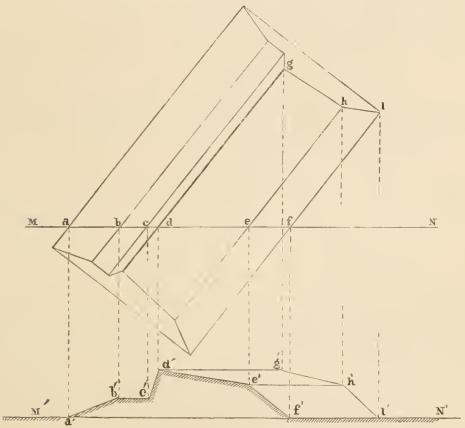


for the ground line; to construct the elevation, draw perpendiculars to M N from the points A, B, C, D, A′, B′, C′, D′, H′, and G′, which we can see when standing on M N, and looking at the work in the direction of these perpendiculars.

Take the points b, c, d, b', c', d', h', at distances from M N equal to their respective heights above ground, join these points as in our diagram, and the elevation is completed.

(69.) A *section* is the intersection of a work by any plane. In Fortification this plane is generally vertical, and it is customary to represent not only the intersection, but also that part of the work which is beyond the plane of section; and the figure which thus consists of a section and an elevation, is called a sectional elevation or merely a section. Let us construct the section of our parapet by the vertical plane whose ground line is M N. In order not to cover the plan with the figure, we draw a parallel M N′ to M N on a convenient part of the paper, and through the points *a*, *b*, *c*, *d*, *e*, *f*, where M N intersects the work, we draw perpendiculars to M′ N′, and take on them the points *a′*, *b′*, *c′*, *d′*, *e′*, *f′*, situated at distances from M′ N′ equal to their respective heights above ground; joining *a′*, *b′*, *c′*, *d′*, *e′*, *f′*, the section is completed, and if we want a sectional elevation, we

Fig. 112.

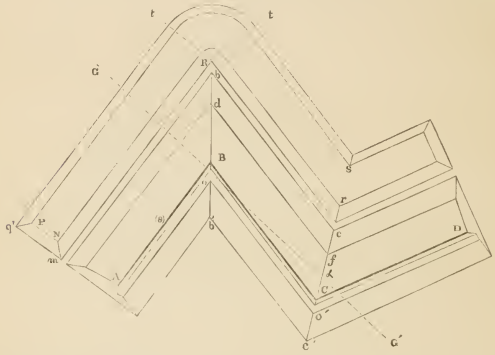


construct it as before, by projecting *g*, *h*, and *l*, in *g′*, *h′*, *l′*, and joining *d′ g′*, *e′ h′*, *g′ h′*, *h′ l′*. To distinguish at once the intersection from the elevation, we etch it as in the diagram. Sections are very useful to convey an idea of the interior of hollow constructions, blockhouses, casemates, &c., to show the thickness of walls, parapets, &c. When the plane of section is perpendicular to the crest, the inter-

section is called a *profile*, and is constructed in the same manner, omitting the elevation.

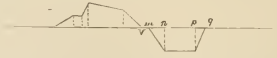
(70.) Let us now construct the plan of a work, the outline of which consists of salient and re-entering angles. This is done exactly as before, repeating for each face the same construction as for a straight parapet. The subcrest A B C being traced, we make a profile to obtain the horizontal distances between each projection, and draw five parallels to A B, B C, C D. These lines cut one another in b', o, B, d, b, d', o', C, f, c; and as the intersections of the slopes are straight lines, we have only to join b' o, B b, and c' o', C c, whilst the banquette being horizontal there is no such intersection of it.

FIG. 113.



In order to draw the plan of the ditch, the profile is calculated and made, from

FIG. 114.

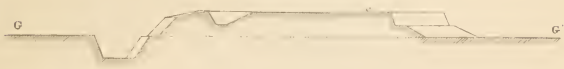


which we have the distances, V m, m n, n p, p q, at which to draw four parallels to the foot of the exterior slope. The limiting slopes at the extremities of the ditch are formed by drawing a line N P parallel to q' m', and $\frac{1}{2}$ or $\frac{1}{3}$ of the depth according as the slope is inclined at $\frac{6}{1}$ or $\frac{3}{1}$, and by joining q' P, m' N.

In the re-entering angles, the ditch is drawn as in *s*, *r*, but at the salients it is usual to trace it with a circle, having, for centre the extremity R of the berm, and limited by the perpendiculars R *t*, R *t'*, drawn from R to the top of the counterscarp.

Elevations and sections are made exactly as in the former example. In the sections on G G′ we have the vertical plane intersecting the line C *f* in *a*, the

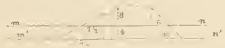
Fig. 115.



altitude of which is not known: to find it, observe that C is 8 feet and *f* 6 feet above ground, and that *a* being in the middle of C *f*, its height is $\frac{2}{4} = 1$ foot below that of C. If *a* had been at the 5th of C *f*, the difference of level would have been $\frac{2}{5}$ foot.

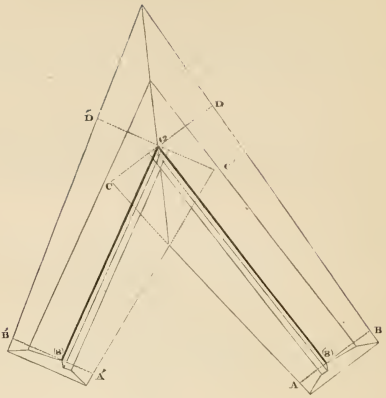
(71.) If the command of the work is greater at the salient than at the extremity of a face (119), it is necessary to construct two profiles. Suppose the commands to be respectively 12 and 8; on *m n* we draw a profile; parallel to *m n*,

Fig. 116.



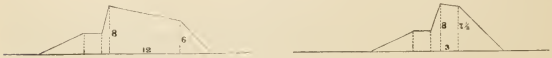
and 4 feet from it draw *m'n'*, and produce the exterior slope and the slope of banquette; the second profile is thus readily found, showing that the horizontal distances are the same for the banquette, interior slope, and parapet, whilst at the salient the slope of banquette is $15\frac{1}{2}$ instead of $7\frac{1}{2}$, and the exterior slope 10 instead of 6. The subcrest (8) (12) (8) being drawn, erect A B, C D, and A′B′, C′D′ perpendicular to it, and on these lines carry the horizontal distances, and join C A, D B, &c. The plan is completed as before.

Fig. 117.



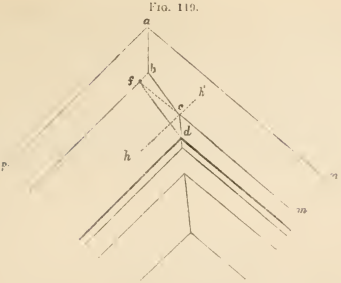
(72.) The faces of a work may sometimes have parapets of different thicknesses, and a beginner may find some difficulty in drawing the intersection of the slopes. Let us, for an example, imagine two parapets, the one 3 feet, the other 12 feet thick, meeting at a salient. If we draw two profiles we see that the

Fig. 118.



exterior crest in the thicker parapet is much lower than the other; when we draw the parallel lines, it would be wrong to trace the intersections of the superior and exterior slopes on *d f a*, since the two exterior crests do not meet in *f*. In order to find the intersection, draw *h h'* parallel to the crest at 3 feet from it; being at the same level as *c m*, it will cut it in *c*, and *c d* will be the first part of the intersection: now as the two exterior slopes are equally inclined to the horizon, their intersection must bisect the angle *n a p*, and coincide with *a b*, and since the points *b* and *c* belong to the two faces, the intersection required will be completed by joining *b c*.

FIG. 119.



These elements of drawing are sufficient to enable a student to understand the various plans, sections, profiles, &c. contained in this work, and to show him how to construct simple drawings. It would be too long to enter into the representation of uneven ground, and the various problems connected with it, such as defilade, &c.; and, moreover, it would be useless, since drawing cannot be learnt entirely from a book: even in attempting his first plans of fortification on level ground, a beginner will need the assistance of a master.

(73.) The outline of a fieldwork is represented by the crest, which is always drawn thicker than the other lines: in permanent fortification the outline is shown by the top of the escarp or cordon. This line, called *magistral*, is marked still thicker in prints, so as to avoid confusion, but when drawn on paper it is marked by a thick red line. The masonry is always traced with red ink, the earth with black, and water with blue. The level parts, such as banquettes, terrepleins of ramparts, barbettes, &c. are left white, whilst the bottom of the ditch is coloured with a flat tint of ochre. The slopes are sometimes shaded with indian ink, and coloured green, The effects of light on receding parapets is showed in elevations by shading; the parts cut in section are also coloured, red for masonry, ochre for earth, blue for water, yellow for wood, &c.; but all these conventional signs are only employed for accurate drawings, such as are prepared by engineer officers for estimates, projects, repairs, &c., &c.

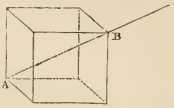
SECTION III.—Isometrical Projection.

(74.) It is often desirable to construct a drawing of an object, which shows at once the three dimensions, length, breadth, height, and which makes on the eye a clear impression of its shape, and at the same time enables us to measure

the true dimensions by means of a scale. Such representation of an object, combining the advantages of a perspective view with those of projections on horizontal and vertical planes, is called its isometrical projection. It is the projection made on a plane, which is neither vertical nor horizontal, but is equally inclined to the three dimensions.

Imagine a cube resting on one of its faces, its edges being vertical, then the plane of projection is perpendicular to the diagonal A B; and as the three right angles in A project in B on a plane, their projection will be equal to a third of 360° or = 120°.

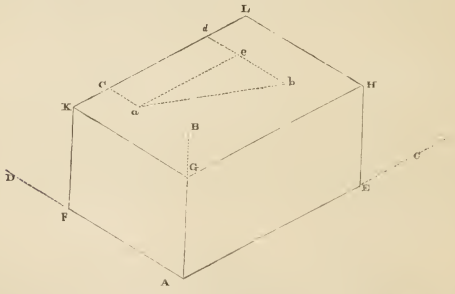
Fig. 120.



Without entering into a mathematical investigation of the method, let us at once show its application, and as a first step represent a rectangular block 12 feet long, 6 feet broad, and 8 feet high, resting on a horizontal plane.

The two lines representing the length and breadth of the base form in projection an angle of 120°, and the vertical edge is equally inclined on each side. Draw, therefore, any vertical line A B, and at any point A make the angles

Fig. 121.



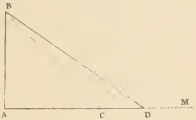
B A C = B A D = 60°, the three lines A B, A D, A C represent the directions of the three edges of one corner, and since the plane of projection is equally inclined

to them all, it is evident that equal lengths taken on these edges are represented by equal projections. Assume any scale for the drawing, and set off A E = 12 feet, A F = 8 feet, A G = 6 feet. Through G draw G H, H K respectively parallel to A E and A F; through F and E draw E H, F K parallel to A B; through K and H draw K L and H L parallel to G H and G K, and the isometrical projection is completed.

In this projection we can measure distances in the three directions A B, A D, A C, or in directions parallel to them, but not in any other; and it should be observed that the scale which we employ for drawing the projection with, cannot be called the scale of the drawing, since any length of the reduced object is greater than its projection.

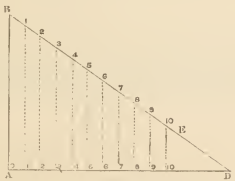
If we have to represent an object at a given scale, say, $\frac{1}{72}$, we must construct the isometrical scale; as the proportion between a line and its isometrical projection is $1 : \sqrt{\frac{2}{3}}$, we must reduce our scale $\frac{1}{72}$ in the same proportion. This is done geometrically: draw two lines at right angles, take A B = A C, and

Fig. 122.



making A D = B C, join B D, then B D : A D :: $1 : \sqrt{\frac{2}{3}}$. Now, make the scale $\frac{1}{72}$ on the line B D; take B E = $1\frac{1}{2}$ inches: this will represent 10 feet; through the points of division draw the parallels 1 1, 2 2, &c. to A B, and we obtain on

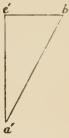
Fig. 123.



A D the isometrical scale, by means of which we can draw an isometrical projection in the proportion of $\frac{1}{72}$ to the natural size.

When we want to measure dimensions in directions different from any of these three axes A B, A C, A D, we proceed as follows: Suppose we wish to ascertain the distance between two points a, b, lying on the upper surface of our block; through a and b draw parallels to K G, and through a a parallel to K L: construct

Fig. 124.

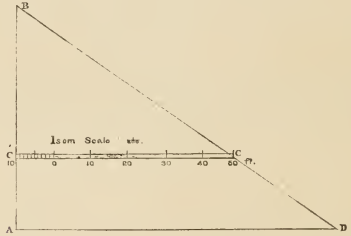


a right angled triangle, in which $a'e' = a\,e$, and $e'b' = e\,b$, the hypothenuse $a'b'$ measured on the isometrical scale gives the true distance.

By way of example let us draw an isometrical projection of a parapet 12 feet high, 2 feet thick, and 30 yards long, at a scale $\frac{1}{300}$.

In a right angled triangle as above, take any convenient length on B D, 60 feet for instance, at the scale $\frac{1}{300}$; this will be represented by B C $= \frac{60 \times 12}{300} =$

Fig. 125.



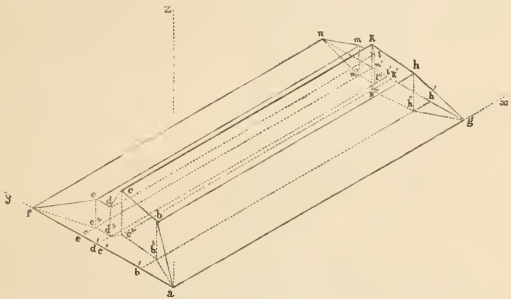
$\frac{1}{5}^{2}$ inches: a parallel $c\,c'$ will be the length corresponding to 60 feet in the isometrical scale, which is easily finished. Drawing a profile of our parapet, to

Fig. 126.

ascertain the various distances, we have all that we require to enable us to construct the projection.

Through any point a draw a vertical line $a\,z$, and two lines $a\,x$, $a\,y$, both inclined at 60° to $a\,z$; one of them, $a\,x$, will represent the direction of the length, the other that of the breadth of the parapet. The plan is first constructed: take

Fig 127.



$a\,b' = 10$ feet; $b'\,c' = 12$ feet; $c'\,d' = 1\frac{1}{2}$ feet; $d'\,e' = 4\frac{1}{2}$ feet; and $e'\,f' = 15\frac{1}{2}$ feet; through b', c', d', e', f', draw lines parallel to $a\,x$. On $a\,x$ take $a\,g = 30$ yards, draw $g\,n$ parallel to $a\,y$, and lastly draw the limiting slopes, at $\frac{2}{3}$ for instance, by setting off $b'\,b'' = h'\,h'' = 5$ feet; $c'\,c'' = k'\,k'' = 6$ feet; $d'\,d'' = e'\,e'' = l'\,l'' = m'\,m'' = 3{\cdot}87$ feet. The figure $a\,b''\,c''\,d''\,e''\,f\,n\,m''\,l''\,k'\,h''\,g$, is the plan of the parapet. The isometrical projection is now readily obtained, if we erect through the various points of the plan vertical lines equal to their altitudes. Thus, through b'', c'', d'', e'', draw parallels to $a\,z$, do the same through h'', k'', l'', m'', and take $b''\,b = h''\,h = 10$ feet; $c''\,c = k''\,k = 12$ feet, $d''\,d = e''\,e = l''\,l = m''\,m = 7\frac{1}{2}$ feet. Join $f\,e\,d\,c\,b\,a$, $n\,m\,l\,k\,h\,g$, and $b\,h$, $c\,k$, $d\,l$, $e\,m$. The line $d\,l$ in this case cannot be seen, and it is either omitted or dotted.

The isometrical projection of any work is constructed in the same manner: first we draw the plan according to the isometrical axis, and next we set off the vertical heights. To complete this chapter, let us apply the method to a square fort of the annexed profile, and in order to find room, let us make the front equal

Fig. 128.

to 320 feet instead of 320 yards. The width of the glacis is, for the same reason, given shorter than it should be.

Draw as before the three isometrical axes, $x\,o\,x'$, $y\,o\,y'$, $z\,o\,z'$, and take the line $x\,o\,x'$ as line of a front. Assume any scale as an isometrical one, and take $o\,a = o\,a' = 160$ feet: the points $a\,a'$ will be the plans of the two salients. In order to get the direction of the faces, we might take a point on the axis $o\,y'$ at a distance $= \frac{1}{6}$ of the front, and join $a\,a'$ to it; but as the directions of the faces are not

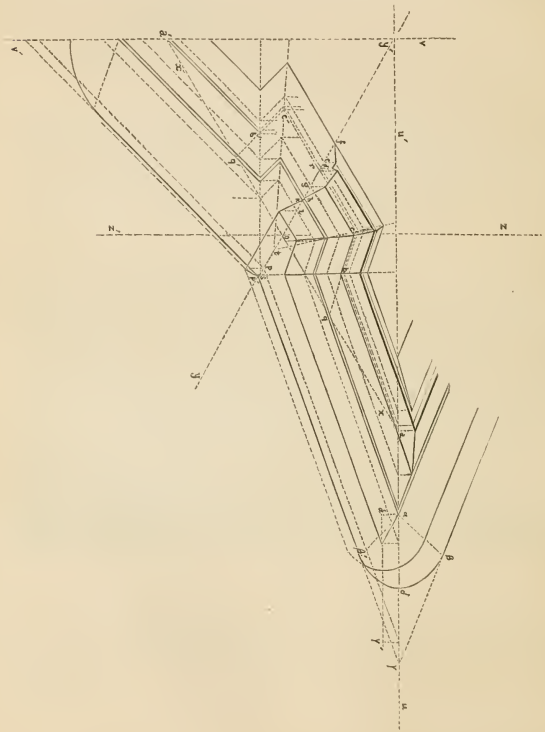
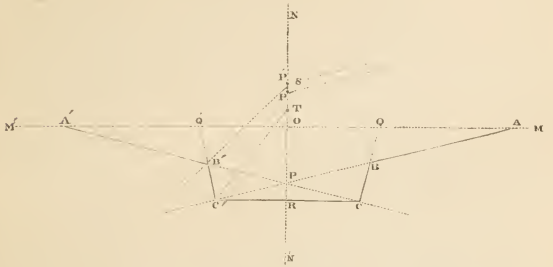


Fig. 199.

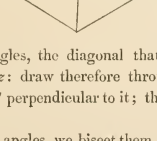
parallel to any of the axes, we cannot carry distances along them, and therefore other means must be found to determine the position of the shoulder angles. In the same scale as before draw a front A B C C′ B′ A′, and produce B C and B′ C′,

Fig. 130.



till they meet A A′ in Q and Q′. Since we can measure distances on lines parallel to the axes, we can do so with lines M M′, N N′; let us transfer to our isometrical plan the distance $o\,r = \text{O R}$; draw through r a parallel to $a\,a'$, make $r\,c = r\,c' = \text{R C}$; take $o\,q = o\,q' = \text{O Q}$, and join $q\,c$, $q'\,c'$, $c'\,a'$, $c\,a$, and $a\,b\,c\,d\,b_1\,a'$ is the isometrical outline. The next step is to bisect the several angles of the outline to obtain the lines of intersection of the slopes. Since the four salient angles of the bastions form the four corners of a square, which is isometrically represented by a rhombus, and since the diagonals of a rhombus bisect the four angles and inter-

Fig. 131.



sect one another at right angles, the diagonal that bisects the obtuse angle is parallel to the vertical axis $o\,z$: draw therefore through a' a line $v'\,a'\,v$ parallel to $o\,z$, and through a a line $u\,a\,u'$ perpendicular to it; these two lines bisect the salient angles.

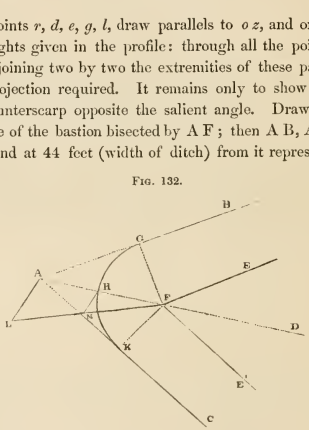
In order to bisect the other angles, we bisect them in the auxiliary plan by B′ S, C′ T which intersect N N′ in S and T, and take in the isometrical plan $r\,s = \text{R S}$, $r\,t = \text{R T}$, and join $s\,b$, $s\,b'$, $t\,c$, $t\,c'$; setting off the distances given in the profile on the axis $y\,y'$, we make $r\,d = 1\frac{1}{2}$, $d\,e = 4\frac{1}{2}$, $e\,f =$

15½, $r\,g = 12$, $g\,h = 10$, $h\,k = 2$, $k\,l = 8$. Through the points thus determined draw lines parallel to $c\,c'$; from the points where these lines intersect $t\,c$, $t\,c'$, draw parallels to $c\,b$, $c'\,b'$, and from their intersections with $s\,b'$ $s\,b'$, draw parallels to $a\,b$, $a'\,b'$, and limit them respectively at $u\,u'$, $v\,v'$. It will remain to represent the counterscarp, covered way, and glacis: now our profile shows that the foot and top of the counterscarp are 62 and 68 feet respectively from the crest, if then in our auxiliary plan we draw two lines parallel to A B and at those distances therefrom, the points P, P′, in which N N′ is cut, are transferred to the isometrical plan, by taking $o\,p = \text{O P}$, $o\,p' = \text{O P}'$: drawing through p and p' parallels to $b\,c$, $b'\,c'$, we have the plan of the counterscarp. The covered way and glacis are done in the same manner.

Those lines of the plan which represent lines lying on the ground, such as the foot of the slope of banquette, the two lines of the berm, and the top of the counterscarp, may be drawn at once; of all the other lines we require only the intersections.

Through the points r, d, e, g, l, draw parallels to $o\,z$, and on them set off the corresponding heights given in the profile: through all the points of intersection do the same, and joining two by two the extremities of these parallels, we obtain the isometrical projection required. It remains only to show how to construct the arc of the counterscarp opposite the salient angle. Draw an auxiliary plan of the salient angle of the bastion bisected by A F; then A B, A C, parallel to the berm at E F E′, and at 44 feet (width of ditch) from it represent the top of the

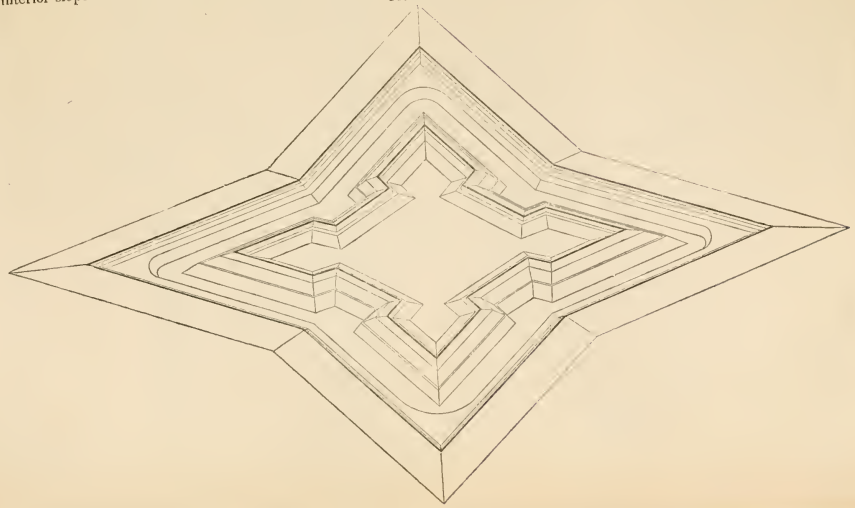
Fig. 132.



counterscarp, and the lines F G, F K, perpendicular to A B, A C, will be equal to the radius of the arc. In the isometrical plan, if from the salient α of the berm we draw $\alpha\,\beta'$ parallel to the flank $c'\,b'$, it will represent the radius of the arc, and a line $\alpha\,\beta$ parallel to the flank of the adjacent front, will also represent it. In this projection $\alpha\,\gamma$ represents the distance A F, and this line must be cut by the arc in

the same proportion as A F is by G H K. Draw therefore F L at any angle with A F, take it equal to $\alpha\gamma$, join A L, and draw H M parallel to A L, the length M F will be the isometrical distance corresponding to H F: making $\alpha\delta = M F$, we have three points β, δ, β', through which the arc passes, and we may at once trace it without any further construction. The foot of the counterscarp is similarly traced, but it must be remembered that in this case the centre of the arc is α' situated 12 feet vertically below α, and that $\alpha'\gamma' = A F$. As in the ordinary elevations, some lines cannot be seen, as the feet of the interior slope and of the counterscarp, but they are seen in the other fronts, where other lines become in their turn invisible.

FIG. 123.



CHAPTER IV.

FIELD WORKS.

The profile of a field-work has already been given, and it has been shown that its standard height is 8 feet; and that the other dimensions are dependent upon the weight of the enemy's metal, and the nature of the soil. The outlines of this sort of work vary *ad infinitum*, but we may classify them under two heads, *Isolated works*, and combined works or *Lines*. The former are subdivided into *open* and *enclosed* works; the latter into *Continued Lines*, and *Lines with intervals*.

SECTION I.—Open Works.

(75). Under this category we place all the works opened at the rear or *Gorge*, and we may reduce them to three types, which are, as it were, the elements of an infinity of others.

1st. The *Redan* or fleche, formed of two faces salient towards the enemy.

Fig. 134.

2nd. The *Lunette*, formed of two faces and two flanks.

Fig. 135.

Note:—The angle formed by a face and a flank is called shoulder angle.

3rd. The *Tenaille*, formed of two faces, presenting a re-entering angle to the assailant.

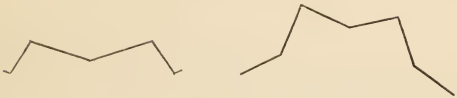
Fig. 136.

Among the many works derived from these, few have received a special name. The *Double Redan*.

Fig. 137.

The *Tenaille Head*.

Fig. 138.



The *Queue d'Hironde*, or swallow's tail.

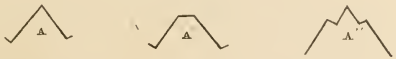
Fig. 139.

The *Bonnet de Prêtre*.

Fig. 140.

All these may be somewhat modified, especially to obtain flanking fire, but they still retain their names; thus—

Fig. 141.



A, A', A'', are still called redans.

The name of *Hornworks*, or Bastion-head, applies in general to all works composed of a bastioned front (78) and two faces.

Fig. 142

That of *Crown Works* to open works containing two or more bastioned fronts.

Fig. 143.

When any one of these works is employed to defend a bridge, it is called a Bridge-head—Tête-de-Pont in French.

A mere inspection of these figures, shows the defects of these outlines when employed by themselves. Thus the Redan and Lunette have no flank defence, and the ground before the salients is deprived of fire. The Tenaille has flanking fire, but its ditch contains a dead angle.

We may here observe, that although these works have by themselves but a weak outline, they are, nevertheless, capable of making a most vigorous resistance when flanked by others in the rear; the inconveniences we have alluded to are besides, as we shall hereafter see, obviated by accessory means, such as artillery, obstacles, &c.

Of the tracing of these works on paper, we say nothing, because their outline varies indefinitely, and the conditions (57, 58), relating to the opening of the salient, and re-entering angles, and to the length of the lines of defence, are the only ones to be observed.

SECTION II.—Enclosed Works.

(76). Here, again, we have three different types—the Redoubt, the Star-fort for fortlet, and the Fort.

A *Redoubt* is an enclosed work having no re-entering angle, and is formed of four, five, or six faces, but generally of four. It may even be circular.

Fig. 144. Fig. 145. Fig. 146. Fig. 147.

The circular redoubt is rarely employed, as it is more difficult to throw up than the others; the square is most generally preferred. The defects of the redoubt are obvious, viz., undefended angles before each salient, and unflanked ditches. In order to remedy the want of fire at the salients, it has been proposed to trace them "en cremaillère," but this plan has not been found expedient in practice.

Fig. 148.

(77). A *Star-fort* presents a series of salient and re-entering angles; the number of salients may be four, five, six, eight, &c.

It is easy to perceive that the Star-forts of four and five salients must be entirely laid aside. Their outline is opposed to principle 58, since the condition of making the salients greater than 60°, gives re-entering angles of 150° and 132°.

Fig. 149.

The Star-fort of six salients is the first, the outline of which is superior to that of a redoubt, its angle of defence being precisely equal to 120°; yet it should not be employed indiscriminately, because the enemy advancing on the capital is only exposed to oblique fire (fig. 150).

In the heptagonal (fig. 151) and octagonal (fig. 152) Star-forts, the capitals

Fig. 150. Fig. 151. Fig. 152.

receive direct fire, which renders these two tracings preferable. Star-forts of a greater number of salients are not employed in the field, because their garrison would be sufficiently strong to defend a fort.

The Star-fort is not so much preferable to the redoubt as would be imagined at first sight, because the greater part of the ditch is dead, the enclosed space is small for the long extent of their parapet, and their faces are exposed to enfilade. Despite the defects of these enclosed works, star-forts and redoubts are frequently constructed; and military history gives us instances of the great value of works having of themselves but a weak outline. Thus, at Montenotte, in 1796, a redoubt, garrisoned with 1500 French Grenadiers, resisted successfully during a day and a night the repeated attacks of 12,000 Austrians. The redoubt of the Stamboul gate at Silistria, in 1854, stood the continuous attacks of the Russians.

The redoubts established in 1855, at Kars, by Colonel Lake, owing to their skilful disposition and mutual flanking, resisted for several months the efforts of the Russians.

A few words may be said on the tracing of these forts:—

1. To trace on paper a Star-fort of six salients, describe an equilateral triangle, trisect each side, and on each centre portion describe an equilateral triangle (fig. 153).

Fig. 153.

2. To trace an eight salients' Star-fort, describe a square, trisect each side, and repeat the above construction (fig. 154).

Fig. 154.

3. This tracing is somewhat improved by replacing the angle of the square by an angle of 60°, since the angle of defence is thereby reduced to 105°. It is done by producing the sides *a b*, *a b*, till they meet in *c*, and joining A *c*, A *c*, B *c*, B *c*, &c.

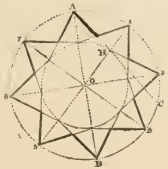
Fig. 155.

4. The eight salients may be made equal. Describe a circle; through the centre draw two diameters at right angles, and bisect each right angle. From the extremity B of a diameter, carry the radius B C on the circumference, the line A C will make an angle of 30° with A B; so will A D. The other salients

Fig. 156.

may be traced in the same manner, or the construction may be further simplified by drawing another circumference with radius O H, and joining each salient to

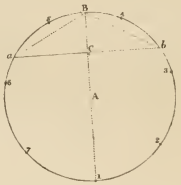
Fig. 157.



the adjacent points of intersection of this circumference, with the lines O 1, O 2, O 3, &c.

5. For the seven salients' fort, describe a circle, draw a radius A B; from B as centre, and radius A B, describe an arc, intersecting the circumference in *a* and *b*, join *a b*. The line *a c* is the side of the regular heptagon, which, carried on the circumference, gives the 7 salients. The construction is completed as for the 8 salients' fort.

Fig. 157*.

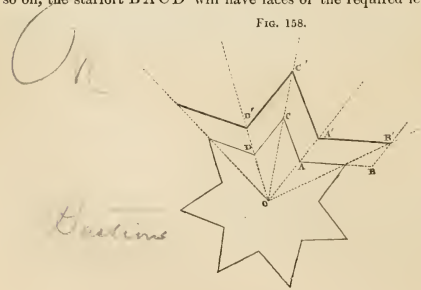


The position of the salients may also be found by means of the protractor, by dividing 360 degrees by 7 or 8, and drawing through the centre, as vertex, seven angles of $\frac{360}{7}$, or eight angles of $\frac{360}{8}$ degrees each.

These methods do not enable us to construct a Star-fort, with faces of a given length, except, however, for the cases 1 and 2, in which the side of the equilateral triangle, and of the square may at once be taken equal to three times the length of the face.

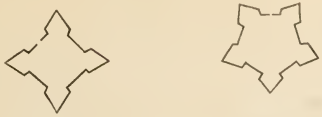
In all other cases, the fort being described of any dimension, join the centre to every angle, and produce the lines thus obtained. In the direction of a face take A B equal to the required length, through B draw B B′ parallel to O A. If now we draw B′A′ parallel to B A, and through A′, A′C′ parallel to A C, and so on, the starfort B′A′C′D′ will have faces of the required length. (*see* 133).

Fig. 158.



(78). A *fort* is the name given to any enclosed work possessing bastions; it may be square or pentagonal.

Fig. 159.



Of bastions.—The serious inconvenience of dead angles has rendered it advisable to adopt a combination of such a kind that in no part of the ditch should a man be sheltered from the fire of the defenders. The bastioned outline, discovered three hundred years ago, for permanent works, completely answers this purpose, and is advantageously employed in field fortification.

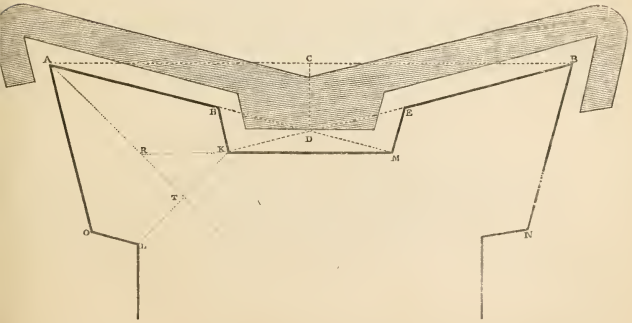
Let us suppose that a work of that kind is to be constructed to defend a position, and let us take the case of a square fort.

The lines A B, B D, D C, C A, which vary from 200 to 300 yards in length, are called fronts, and for each of them the construction is the same.

Fig. 160.

On the middle of the line A B, a perpendicular C D, called the *perpendicular* of the front, is drawn; and towards the interior, a length C D is taken, equal to $\frac{1}{8}$th of the front. Join A D and B D; on these two lines measure the

Fig. 161.



distances B E and A H, each equal to $\frac{1}{3}$rd of the front; from H draw H K perpendicular to K B, and from E, E M perpendicular to M A. Join K M, and A H K M E B will be the outline of the bastioned front, which consists of two half bastions and a *curtain* K M.

The same construction being repeated on each front, a *bastion* K H A O L is obtained.* The lines H K, E M are called *flanks;* A H, B E, *faces;* K L, the *gorge* of the bastion; A T, the *capital;* K R, the *demi-gorge;* A M, B K, the *lines of defence.* The angles H A O, E B N, are the salient or *flanked angles;* H K B, E M A, the *angles of defence;* H K M, E M K, the *angles of curtain,* or of the flank; A H K, M E B the *shoulder angles;* and C A D, C B D the *diminished angles.*

On inspecting this outline, it will be perceived that at whatever point the enemy presents himself, he is exposed to cross fire in several directions; and that if D M is greater than 30 yards, there is no longer a dead angle.

The length of the perpendicular, fixed at $\frac{1}{7}$th of the front for the square, is made $\frac{1}{8}$th for the pentagon, and $\frac{1}{9}$th for figures of a greater number of sides.

In hornworks and crownworks the same construction is adopted, but the perpendicular which has been fixed for enclosed works so as to give more than 60° to their salients, may now vary from $\frac{1}{6}$th to $\frac{1}{11}$th.

Many engineers object to the employment of bastioned fronts in the field, because the defenders on the flanks are liable to fire at each other; but there is no doubt that for an important position the bastioned tracing is the best. In order to give more fire on the salients, the curtain has occasionally been broken,

Fig. 162.

Fig. 163.

as in these diagrams; but it becomes exposed to enfilade. The same may be said of several other tracings, such as the accompanying.

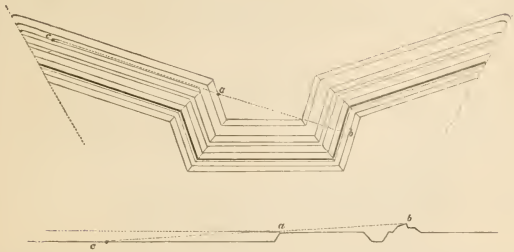
Fig. 164.

When the ditch of a bastioned front is excavated parallel to the faces, flanks,

* This word comes from the Italian 'bastido,' a tower; bastions made of earth were invented to replace in permanent fortification the tower that flanked the walls of a town, after the discovery of gunpowder and the use of artillery.

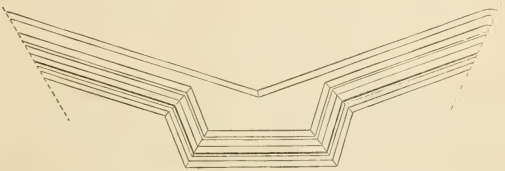
and curtain, one of the great advantages obtained from this tracing is lost, as may be seen by making a profile on *b c*.

Fig. 165.



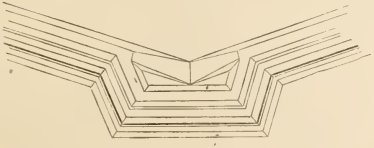
The shot grazing the counterscarp in *a* does not reach the bottom of the ditch until *c*, and with the ordinary relief, *a c* measures 70 yards. It becomes necessary, then, to excavate the ditch, as below, which entails great labour.

Fig. 166.



When time is of importance, the amount of excavation may be reduced by

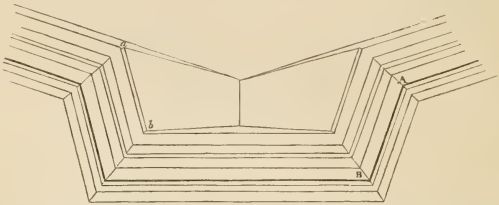
Fig. 167.



cutting a ramp in the prolongation of the escarps and counterscarps of the faces of the bastions, but the ditch of the flanks is still without defence.

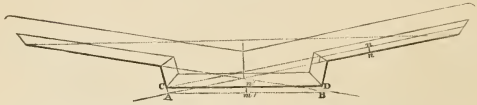
To avoid this defect, the whole mass of earth before the curtain may be cut into a glacis, the (plane) surface of which passes through the crest A B of the flank, and a line $a\,b$, situated 2 feet above the bottom of the ditch.

Fig. 168.



Another modification of the original tracing, which has been made for the purpose of diminishing the deblais, consists in bringing the original curtain A B forward to C D to the distance $m'n' = m\,n$ = thickness of the parapet, because

Fig. 169.

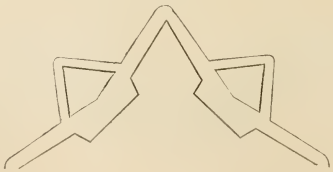


the part C A of the flank does not contribute to the defence of the ditch; but it is not an improvement as far as the outline is concerned.

We may also state that if the flanks are merely intended to flank the ditch, a perpendicular $= \frac{1}{7 \cdot 5}$ is sufficient for that purpose, but the tracing becomes far inferior to the original one.

Sometimes a small redan is placed before the curtain, to give flanking fire on

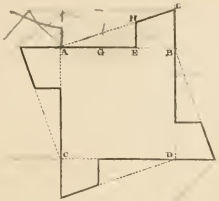
Fig. 170.



the capitals of the bastions, but its small saliency does not prevent the enemy from attacking the bastions.

(79.) The demi-bastioned fort has sometimes been employed. It is described on a square A B C D. Trisect a side A B in G and E. Produce the adjacent side, making B L = B E, join L A, and erect E H perpendicular to A B, and

Fig. 171



repeat the same construction on every side. This is a bad work, having as many dead angles as half bastions.

(80.) Among enclosed works we may place *block-houses;* these are employed in woody and mountainous countries where timber abounds, and where artillery is not likely to attack them. Their outline varies; the square and the

Fig. 172.

cross being the most general forms. The walls are formed of logs of wood from 9 to 12 inches square, buried 3 feet, connected to sills and cap-sills, the latter consolidated by girders. The interior should be 20 feet wide, and 9 high in the clear. Loopholes are pierced 3 feet apart; and a banquette, serving as a

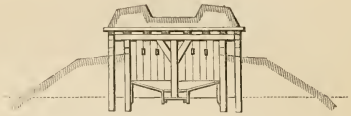
Fig. 173.

camped, allows the men to fire through them. A parapet of earth and a ditch prevent the access of the enemy.

When artillery can be brought against these works, their wall is made of two rows of logs, the space between the timber being filled up with earth well rammed in.

The profile of their walls varies much.

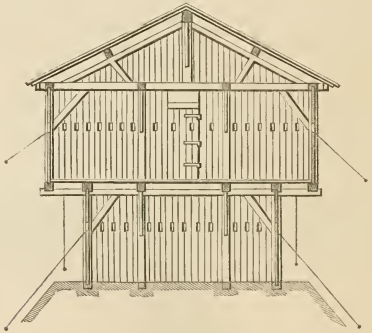
Fig. 174.



The roof is covered with earth 3 feet thick to avoid fire, and render it bomb-proof, and is sometimes furnished with a banquette.

Sometimes the blockhouse has two stories, (*See* fig. 175) and machicoulis are pierced in the projecting floor to defend the foot of the lower story. The men enter the upper story by means of a ladder.

Fig. 175.



These works make good defensive barracks in a hostile country.

Blockhouses were erected in 1849, in the bastions of Vienna, commanding the principal streets, as a defence against future internal enemies in the Austrian capital.

SECTION III.—Continued Lines.

Lines is the name given to the intrenchments constructed to fortify the position of an army, or to connect important forts or redoubts. According to their object, they are called *Intrenched Positions, Intrenched Camps, Lines of Circumvallation, Lines of Contravallation;* but the two last are obsolete. (199.)

With regard to their arrangement, they either cover the ground without interruption, or are composed of works combined for a common defence; in the first case they are called Continued Lines, in the latter, Lines with Intervals.

(81.) *Continued Lines* are generally to be avoided, on account of the amount of labour they require, which bears no proportion to their value; in fact, the defenders may expect an attack on every point and prepare for it, whether real or false, and when once the line is forced at a point, it is altogether lost. Yet, there are circumstances, when they are advantageously employed, as, for instance, to cover a besieging army.

Their outline varies indefinitely. The chief sorts may, however, come under the following heads:—

The *Tenaille Lines.*

Fig. 176.

The *Lines of Vauban* or *Redan Lines,* with small or large Redans.

Fig. 177.

Continued Redan Lines.

Fig. 178.

Indented Lines.

FIG. 179.

Bastioned Lines.

FIG. 180

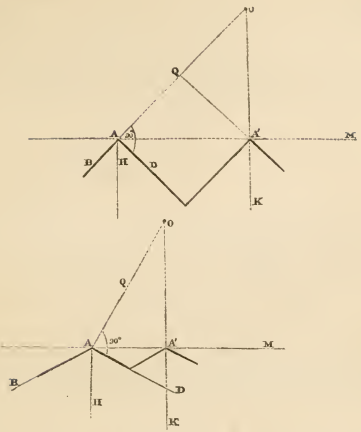
(82.) In these works we call *line of front*, the line that joins all the salients, and *zone of defence*, the ground situated before them as far as a line parallel to the front, and on which the enemy is within range of musketry, the fire being supposed to be perpendicular to the crest of the parapet. The deeper this zone the better, since the enemy remains exposed during a longer time.

A discussion on some of these continued lines will give an idea of the principles on which they should be traced.

(83.) *Tenaille lines*:—As their salient and re-entering angles are necessarily equal, the opening of these angles can only vary between 90° and 120°. The *minimum* of the faces is already known as 30 yards (59). To find the maximum distance between the salients, the following method will apply to any sort of tenaille.

A salient B A D being traced in direction, together with the line of front A M, and a line A Q being drawn perpendicular to the face A D, to represent the direction of the last shot, it is clear that the capital of the next salient should cut this line within range. Therefore, on A Q, measure A O equal to the range given, through O draw O K parallel to the capital A H, and the point A′ where this line intersects the front, gives the position of the next salient required. Supposing the range to be 300 yards, the following results may be noticed.

Fig. 181.



Tenailles of	Faces.	Distance between salients.	Depth of zone of defence.	Perimeter for 1000 yards.
90° ...	150 yards ...	212 yards ...	212 yards ...	1414
100° ...	125 ,, ...	192 ,, ...	229 ,, ...	1305
110° ...	104 ,, ...	171 ,, ...	245 ,, ...	1220
120° ...	86 ,, ...	150 ,, ...	259 ,, ...	1154

The inspection of this table shows that it is advantageous to open the angles to the maximum of 120°, since the labour is diminished whilst the depth of the zone of defence is increased. Besides, the enemy cannot enfilade them so easily, being obliged to come nearer the front to do so.

In general, the tenaille trace has the drawback of presenting many points of attack, of requiring much labour, and of being exposed to enfilade.

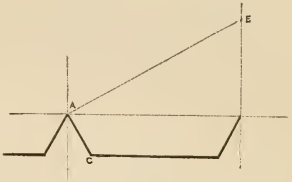
(84.) *Lines of Vauban* or redan lines:—Vauban usually constructed two sorts of lines, those with great redans and those with small redans. The great redans had 80 yards gorge and 55 yards capital, the small ones 60 yards gorge and 44 yards capital. In both cases the salients were placed 240 yards apart.

This tracing was bad, because the angles of defence were greater than 120°, and the undefended angles were not flanked within proper range for the old musket,

whilst in front of the curtains where the enemy does not attack, the fire crossed in three directions.

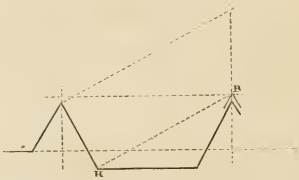
The defect of the angles is now remedied, by making the redans equilateral triangles of 60 yards face. The distance of 240 yards, would not be too much at present. However, the range being given, the maximum distance between two salients is found as for the tenaille by taking A E, perpendicular to A C, and equal

Fig. 182.



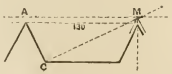
to the range. A further improvement may be made in this maximum line, by lengthening the faces of the redans, till they meet the perpendicular B H, drawn upon their direction from the exterior crest of the adjacent salient.

Fig. 183.



The minimum distance is obtained by the condition, that the last shot from the face at C, shall graze the salient of the parapet in M. In this case the distance is 130 yards.

Fig 184.



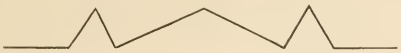
Supposing the range 300 yards, the maximum distance between the salients is

260 yards. The perimeter of the parapet for 1000 yards of front, is equal to 1230 yards for the line maximum, 1500 yards for the same modified, and 1615 yards for the line minimum.

The depth of the zone of defence is 248 yards.

It has been proposed to alter the tracing of Vauban in a different manner by

Fig. 185.



breaking the curtain, but it is evident that it gives a greater number of points of attack, and that the branches that replace the curtain become exposed to enfilade.

Another form of the redan line, is the following, which is sometimes called the caponier tracing.

Fig. 186.

(85.) *Indented lines.*—Two sorts have been employed, respectively called great and small "crémaillère." The line of front was divided into equal parts of 120 or 90 yards, and perpendiculars of 40 or 30 yards drawn through the points of division. By tracing the diagonals of the rectangles thus obtained, either to the right or left, and dropping perpendiculars from the point of division upon them, a

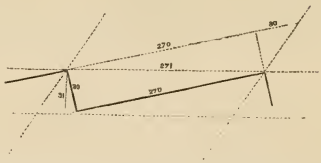
Fig. 187.

line was obtained which easily adapted itself to all varieties of ground. These lines are more advantageously employed along the side of hills, as the short branches by an increase of command, admit of an easy defilade (Chapter VII.) The long branches, owing to their inclination to the front, render the enfilade difficult, as the batteries of ricochet must be established rather near the front.

In taking the range into account, and adopting 30 yards for the minimum flank, the greatest distance between two salients is found by the condition that the shot from one salient shall reach the capital of the next. With a range of 300

yards, it is evident that the long branch measures 270 yards, and that the sides of the rectangle are respectively 271 yards, and 31 yards.

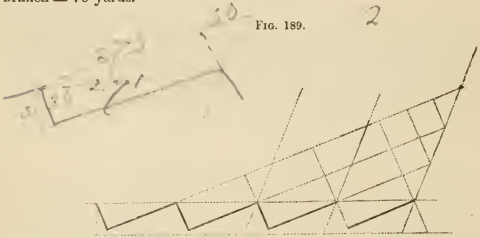
Fig. 188.



In giving any dimension to the flank, the range must always be equal to the sum of the short and long branches. In the example selected, the zone of defence measures 284 yards, and the perimeter 1265 yards.

To generalize the tracing of this sort of line, let us calculate the dimensions of a cremaillère, in which the shot from one salient, will reach the capital of the third salient, the range being 300 yards. Giving 30 yards to the flank, the inspection of the figure shows that the range must be equal to 3 times the sum of the long and short branches; hence $300 = 3 \times 30 + 3$ times long branch, and long branch $= 70$ yards.

Fig. 189.

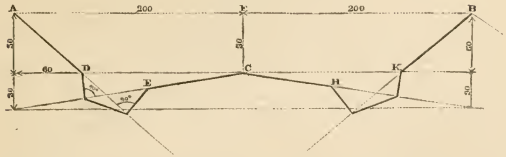


To protect these lines from enfilade, the original tracing is sometimes altered as in the annexed diagram, where the long faces are directed to a point on which it is supposed the enemy cannot establish himself.

Fig. 190.

(86.) *In Bastioned Lines*, the front to be fortified is divided into partial fronts of 200 yards, and on each of them the construction of No. 78 is repeated. The tracing that follows has been proposed to diminish the number of the salients

Fig. 191.



of attack, C E is taken equal to A D, and the flanks are traced perpendicular to the lines of defence. The ditch, however, is not well flanked, owing to the small dimensions of the curtain.

SECTION IV.—Lines with Intervals.

(87.) These are formed of detached works, placed at such intervals as to derive protection from one another, and so as to cross their fire on the intervening space. Different outlines may be selected, two or three rows of lunettes, or two or three rows of redoubts.

Fig. 192.

Fig. 193.

Such lines can be more easily adapted to the ground, and occasion less labour; they permit the defenders to move rapidly and in force on the intervals to repel

the attack, and assume the offensive when the opportunity presents itself; an immense advantage over Continued Lines, where the defensive attitude is compulsory.

During the seventeenth and even the eighteenth century, continued lines were frequently employed to cover an army engaged in besieging a fortress, or to defend a position; but experience has made us wiser: we no longer employ them in a siege, and we have recourse to lines with intervals whenever we have to defend a position of some extent.

At Arras, in 1634, Turenne made three false attacks on the lines constructed by Condé and the Archduke Leopold, and succeeded in forcing them.

In 1656, at Valenciennes, the lines of Turenne were also forced by Condé.

In 1706, at Turin, Prince Eugene defeated Marsin, who awaited him behind his lines.

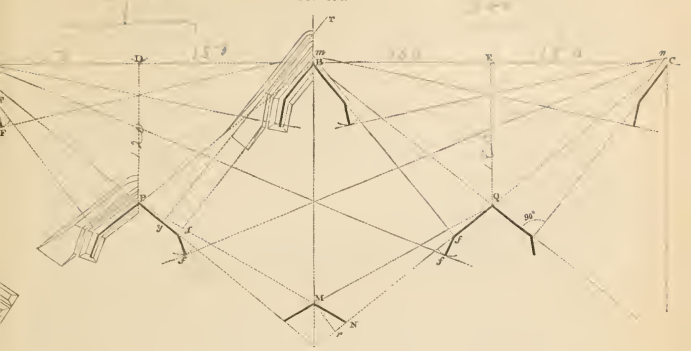
In 1793, the Prince of Cobourg, commanding the Austrian forces (60,000 men), was attacked in his lines at Wattignies, by General Jourdan, at the head of 40,000 French troops, and was compelled to raise the blockade of Maubeuge.

It was during the Seven Years' War that the Prussians and Austrians had recourse to powerful combinations of lines with intervals. The most remarkable were those of the King of Prussia, near Jauernig; those of H.R.H. Prince Henry, near Liebenthal, in 1759; those at Colberg, in 1761; and those of the Austrians at Dippoldiswalde, in 1759; at Boxdorff, in 1761, and upon the high Eulengebirge, in 1762. In the Peninsular war the most celebrated were those constructed at Torres Vedras, by the Duke of Wellington, in 1810.

(88). *Lines with Intervals.*—The following formula for tracing a line with intervals may be taken as a fair standard.

Divide the line of front into parts of 300 yards, A B, B C. Bisect them in D, E, and through these points draw perpendicular D P, E Q, measuring 120 yards. Join A P, B P, B Q, C Q, and on these lines take 40 yards on P *f*, Q *f*, to obtain the faces of the lunettes of the second row. If the points A, B, C, &c. are respectively joined to the extremities *f*, *f*, of these faces we obtain the direction of the faces of the lunettes of the first row, which can also be made 40 yards long. This tracing will protect the second line against enfilade, and the angle of defence will measure 90°. The flanks are made 20 yards long, so as to receive four guns. To trace them, from the shoulder angles of the lunettes as centres, describe circles of 20 yards radii. By drawing tangents *m* F, *n f*, &c., to these circles through the salient of the crest of the parapet of the first lunettes, the point of contact gives a second point of the flank, which will therefore make an angle of defence = 90°.

Fig. 194.



An additional row of works can be obtained by producing the faces Pf, Qf, of the lunettes of the second line, measuring 20 or 30 yards on rM, and joining Q M and P M. These redans are not exposed to enfilade. A fourth line of works would be superfluous, as the force which would allow the three rows to be carried could not be expected to defend a fourth.

The defensive properties of this line are great, for the assailant must carry three works of the first row, two of the second, and one of the third, altogether six works before an opening can be made. The amount of labour for 1000 yards is only 1000 yards of parapet.

It is usual in all lines with intervals to construct the ditches of the works of the first and second rows, parallel to the faces and slanting into a ramp, so as to expose it entirely to the fire of the work in rear.

Fig. 195.

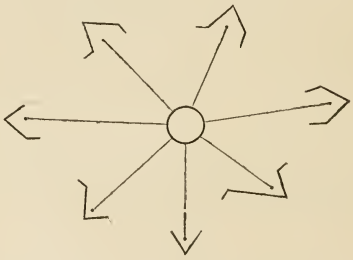
(89.) To complete the nomenclature of field-works, there remains only to mention the *réduits*, or interior retrenchments. They are works of any outline thrown up in the interior of a large work (fig. 196), and overlooking the sur-

Fig. 196.

rounding terreplein, either to serve as a place of refuge to the garrison and facilitate its retreat, or to keep possession of the principal work with a small force. Such reduits are difficult to establish in the field, inasmuch as they imply a work of great magnitude, and, unless the ground be very uneven, they would be too much exposed to the plunging fire of the enemy mounted on the parapets of the intrenchment. Besides, if the garrison perform its duty, it will remain on the banquettes to the last moment, and the enemy would enter into the reduit pèle-méle with the defenders. If, however, this interior retrenchment be placed in some re-entering part, where the defenders can retire under the protection of its fire, it may become most useful. When a garrison, after having repulsed several assaults, has been reduced to a small number, and has become too weak to hope for a vigorous resistance, a reduit can then serve as a refuge and a citadel.

A circular redoubt, although deficient in outline on account of its diverging fire, has sometimes been found an excellent reduit for a system of opened works.

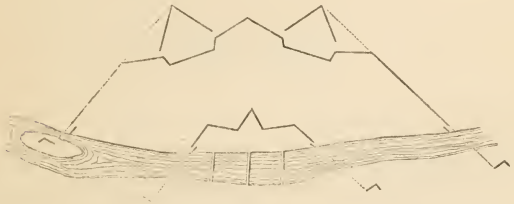
Fig. 197.



A block-house may serve as a defensive barrack and interior intrenchment, to guard a larger work. In mountainous countries, among hostile populations, such block-houses surrounded by field-works, which the garrison can defend if necessary, have been found most advantageous to occupy the chief passes with, and to protect the resting-places of convoys with.

It is chiefly in the works destined to cover bridges (183) (têtes-de-pont) that interior retrenchments are met with in the field. They are, in fact, indispensable. When the army retreats, it first collects behind the principal work, whose artillery and musketry delay the advance of the foe, and give time to the troops to cross

Fig. 198.



the bridges. As soon as the principal work has fulfilled that purpose, the reduit continues to keep the enemy in check in the terreplein in front, covering the last retreating body; and, as soon as the bridges have been destroyed, its small garrison hastily retires on rafts or in boats kept ready for that purpose. The tête-de-pont of Cassel, constructed by the French in 1792, was intended to allow space for 20,000 men to fight, and yet it could be defended by 3000 men only. The works thrown up at Nordheim, on the Rhine, in 1744, by the Prince of Conti while retreating, afford an example of the most judicious employment of the têtes-de-pont with reduits. The têtes-de-pont erected on the Vistula in 1806 and 1807, those on the Danube in 1809, that at Dresden in 1813, that of Praga, on the Vistula at Varsovia, &c., present similar dispositions.

CHAPTER V.

SELECTION OF FIELD WORKS.

The *ground* is the first element to be considered before selecting a particular outline, but it is not the only one. We must also bear in mind the *end* for which the work is designed, and the force of the *garrison* destined for its defence. Again, the amount of labour, and the *time* required to throw up the work, may further induce us to modify this outline.

(90). With regard to the ground, and the purpose of the work, no absolute rule can be laid down; here all is left to the ingenuity of the officer, and it should never be forgotten that it is not by difficult and complicated tracings that skill is displayed.

If a bridge thrown across a river is to be defended by a work, the figure shows that a redan (fig. 199) would not answer the purpose if the river runs in a

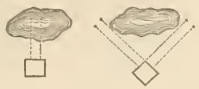
Fig. 199.

straight line, the assailant being in fact unexposed in his approach on the ground A and B; this outline would, on the contrary, be good when the river presents sinuosities: the lunette should be preferred on the former supposition (fig. 200).

Fig. 200.

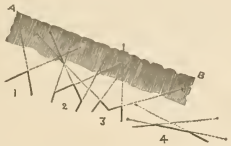
If a marsh or ground impassable to the enemy is in the vicinity of a position, it would be absurd to place a face parallel to the obstacle, since its fire would be lost. On the contrary, in directing a salient towards it, we at once obviate the disadvantage of the want of fire on the capital (fig. 201).

Fig. 201.



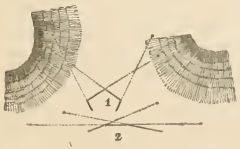
If a work must be thrown up close to a commanding height, the outlines 1, 2, 3, would give faces exposed to enfilade and reverse fire, and therefore the outline 4 should be preferred (fig. 202).

Fig. 202.



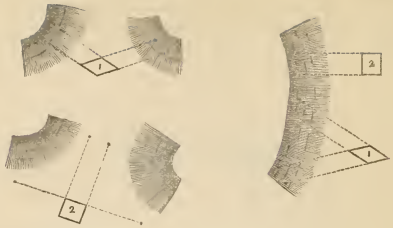
If the work is to be constructed in a valley between two commanding heights, outline 1 would again be absurd, so would be any other than figure 2 (fig. 203).

Fig. 203.



Again, the redoubt 1 has all its faces exposed to enfilade and reverse fire, while redoubt 2 has better conditions (fig. 204).

Fig. 204.



Examples of this kind could be multiplied *ad infinitum*, but a perusal of former campaigns is the best exercise that can be recommended to an officer desirous, in time of peace, of acquiring information, if not experience, on this important subject.

In general, none but good positions should be fortified, and the command should, as much as possible, be obtained from the ground itself rather than from high parapets. In hilly regions, the summits are good points to occupy, because a command of 5 to 6 feet is sufficient for cover; but in general the crests are not sharply defined, and the works must be constructed on the side of the hill, in order that the whole slope may be seen. Should the crests have salient points, of course these should be preferred.

(91). As for the object in view, it may be said that, in general, *redans* are employed to cover the front of the enemy, to defend a road, a bridge, a dam, a gate, &c., when the gorge is not exposed to be turned. A *lunette* will answer the same purpose when the flanks can defend some parts of the grounds not seen from the faces. Double redans, *queues d'hironde*, *bonnets de prêtre* are preferable when the extent of ground is greater. *Horn works* and *crown works* scarcely belong to field fortification: they serve for the defence of several bridges, as *reduits* for intrenched camps, &c. Of the inclosed works, *redoubts* are constructed to secure an advanced post, to occupy a defile, to support the wings of an army, to flank lines of intrenchments, to defend an inundation, covering the front of a position exposed to be turned, &c.

Star-forts and *forts* have a similar purpose when the garrison is more numerous, and when the position must be occupied for a longer time.

When the operations of an army render it necessary that a position should be fortified and occupied for the whole campaign, the works assume more importance, and may consist of forts having 5 or 6 bastioned fronts. Such a fort is

called a "*place du moment.*" An open town in which magazines, hospitals, &c., are established, is frequently transformed into a field fortress, and it should possess such outline and profile, as to oblige the enemy to make a regular siege.

(92). To calculate the garrison of a work already constructed, we measure the perimeter of the parapet, and allow one or two men per yard; but with such a force the defence will be slack, and it is better to allow two men per yard, plus a reserve of one-third the whole garrison, *i. e.*, a man per foot.

If a lunette has 90 yards of parapet, the garrison will muster 270 men, of whom 180 are stationed on the banquette, and 90 are kept as a reserve.

Should two ranks and file be deemed necessary, the garrison would be 540 men, 360 on the banquette, 180 as reserve; but the former number is quite sufficient for a vigorous resistance. Let it be understood that in measuring the perimeter, we do not include the part occupied by guns.

When the garrison is given, and the outline of the work is optional, we act on the same principle. Let us suppose that we have to throw up an open work for 480 men. Of these, 320 will be on the banquette, and 160 on reserve; at the rate of two men per yard the perimeter of the parapet is 160 yards. This length is then devised into the outline that will best suit the ground.

In this example, a double redan will be preferable to a redan of 80 yards faces (fig. 205).

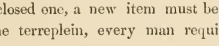
Fig. 205.

In this calculation, allowance should be made for guns, at the rate of 15 feet each, and 40 feet for those in capital.

When the work is an enclosed one, a new item must be taken into consideration, viz., the area of the terreplein, every man requiring 15 square feet to bivouack.

In star forts and bastion forts there is always more interior space enclosed than is required for the garrison, but in square redoubts the case is different. The distance between the subcrest and the terreplein being 12 feet, it is clear that there would be no terreplein when the side of the redoubt is equal to, or less than 24 feet, or than 27 feet when the banquette must be 4 feet 6 inches wide.

Fig. 206.



A few examples will illustrate the march to follow.

Let us calculate the dimensions of a square redoubt for 350 men, of whom any number may act as reserve.

Each man requiring 15 square feet, the area of the terreplein should measure $15 \times 350 = 5250$ square feet. The mass of earth (traverse) usually erected to

FIG. 207.

cover the passage, for the ingress and egress of the garrison, absorbs 1000 feet, so that the whole area should measure $5250 + 1000$ or 6250 square feet. The square root of 6250, *i.e.* 79, gives the side of the terreplein, and adding 24 to it, we find the side of the redoubt equal to 103 feet.

Should the redoubt be intended to contain guns, we allow 500 square feet for each piece, which includes room for gunners and ammunition, and 500 square feet extra for every barbette (96).

The side of a redoubt intended for 300 men with two guns en barbette, and three in embrasures must have a terreplein of area $= 300 \times 15 = 4500$ for men, $+ 1000$ for traverse, $+ 500 \times 5 = 2500$ for guns, $+ 500 \times 2 = 1000$ for the barbette; altogether 9000 square feet. The side of the terreplein will therefore be 94 feet, and that of the redoubt 118 feet.

This calculation is made whenever the garrison has to occupy the redoubt for a considerable time, and must therefore bivouack in it; but when it is thrown up for an occupation of a few hours only, the dimension of the terreplein is altogether neglected, and we calculate the side of the redoubt by the general method. Let us, for instance, suppose that a redoubt is to be constructed for 240 men, with 3 guns along the parapet, and one in capital. If nothing is said of the number of men allowed for every lineal yard of parapet, we adopt the ordinary rate of 2 men and a reserve. Of these 240 men, $\frac{2}{3}$ or 160 will line the parapet, the remainder, 80, acting as reserve. The 160 men require $\frac{160}{2} = 80$ yards of parapet, or 240 feet; the guns must have $15 \times 3 + 40$ or 85 feet. Thus the perimeter of the redoubt measures $240 + 85$ or 325 feet, the side therefore $= \frac{325}{4} = 81$ feet.

It may readily be seen that such a redoubt cannot give accommodation for its garrison on the terreplein, since its area measures only $(81-24)^2 = 3249$ square feet, whilst the men, traverse, and guns require 7100.

When the redoubt is to be defended by a certain number of men per lineal yard of parapet, and must at the same time accommodate its garrison on the terreplein, it is easily seen that the problem is not indeterminate, but that there is a minimum side with a corresponding minimum garrison, under which the two conditions cannot be made to agree. We must have recourse to algebra to solve this problem.

Let us suppose that such a redoubt must be constructed with one man per lineal yard of parapet. Let N represent the garrison and X the side of the redoubt in feet. The garrison $N = \frac{4X}{3}$, and as every man requires 15 square feet, and the traverse 1000, the terreplein $(X-24)^2 = 15\,N + 1000$. In solving the equations, we find $X = 73$, $N = 97$. Hence, no redoubt with a face smaller than 73 feet can be made which will hold its garrison, and be defended by one man per yard; but any redoubt larger will do it, since the area of the terreplein increases more rapidly than the perimeter.

A similar minimum may be found for a defence by two men per yard; the equations would be respectively $N = \frac{8X}{3}$; $(X-24)^2 = 15\,N + 1000$, giving $X = 92$, $N = 245$.

For a defence by two men and a reserve $N = 4\,X$; $(X-24)^2 = 15\,N + 1000$, from which, $X = 101$, $N = 404$.

Should the redoubt contain guns, the method remains the same.

To conclude, let us find the smallest redoubt capable of holding two guns in barbette in capital, and one in embrasure, besides its garrison and reserve. $4\,X = N + 2\times 40 + 15 = N + 95$; $(X-24)^2 = 15\,N + 3\times 500 + 2\times 500 + 1000$
$= 15\,N + 3500$

The garrison $= 385$ men, the side 120 feet.

(93.) We have said (92) that star-forts and forts need no such calculation. Their dimensions are determined on different principles. The question may naturally suggest itself, when should we construct a redoubt, or a star-fort, or a fort? Supposing the consideration of the ground to be laid aside, we give the preference to the fort, next to the star-fort, since their outline is superior to that of a redoubt.

If in a star-fort the faces are less than 15 yards, the ditch is entirely dead, and the defenders cannot even see the ground immediately in front of the salients; such works are not so good as redoubts, since they have their defects, and are more exposed to enfilade. But when the faces are above 30 yards, the ditch is seen at the salient by the defenders, and the outline possesses good properties. We therefore lay it down that the faces should be at least 30 yards long. The minimum perimeter of a star-fort of six, seven, and eight salients will, therefore, be 360, 420, 480 yards. Hence, when calculating the perimeter of a redoubt for a given garrison, if we find it above 360 yards, we should prefer constructing a star-fort. The maximum of 160 yards has been fixed by some authors for the perimeter of a redoubt, because they consider a star-fort of 15 yards face a possible work, but the generality of engineers allow 360 yards.

The perimeter of the smallest square fort, with a front of 200 yards, measures

920 yards, therefore the longest face which should be given to the three star-forts should be $\frac{920}{12}$, $\frac{920}{14}$, $\frac{920}{16}$, or 77, 66, and 57 yards. Above that a square fort can be constructed.

(94.) To conclude this Chapter, a few words on the minimum and maximum of bastioned fronts may be added, for the use of more advanced students.

One of the great advantages of the bastion trace is, that it has no dead angle; but we have seen that this result is only obtained by excavating the ditch, before the curtain and flanks, as far as the counterscarp of the faces. Yet, if the front is less than 200 yards, this advantage no longer exists.

To avoid the dead angle, it is necessary that the planes of fire of the flanks should meet the bottom of the ditch, precisely in front of the middle of the curtain. With a command of 8 feet and a depth of 9 feet for the ditch, the distance M N = 34 yards.

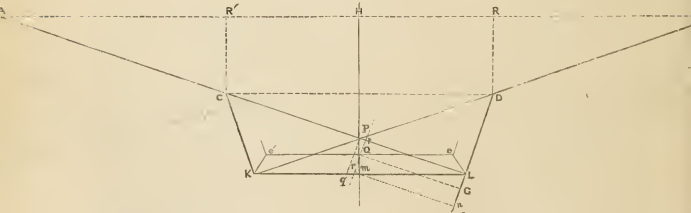
FIG. 208.

With a mean parapet of 12 feet, a berm of 1 foot, and an escarp at $\frac{1}{4}$, the distance N Q = 7·83 yards.

By means of M N and N Q, the *minimum* of the front is calculated.

Let A C K L D B, represent the line of fire, e e' the foot of the escarp before the curtain: the distance L p = Q G = 34 yards, and Q m = 7·83. Through m, draw r n, parallel to L P, and through P, draw P q, parallel to D L.

FIG. 209.



The triangle A H P gives:—

A H : A P : H P :: 4 : $\sqrt{17}$: 1 for the square.
A H : A P : H P :: 7 : $\sqrt{53}$: 2 „ pentagon.
A H : A P : H P :: 3 : $\sqrt{10}$: 1 „ hexagon.

In Q r m, similar to A H P, the above proportion gives us respectively in

	Square.	Pentagon.	Hexagon.
$r\,m$ =	1·899	2·151	2·476
Therefore $m\,n$ =	32·10	31·849	31·524
In m L n also similar:—			
m L =	33·087	33·12	33·229
Therefore K L =	66 174	66·24	66·458
In P m L also similar:—			
P L =	34·105	34·444	35·026
In P L q also similar:—			
P q =	8·526	9·841	11·675
L q =	35·154	35·82	36·92
Therefore K q =	31·020	30·42	29·53
As P q is parallel to D L, K q : K L :: P q : D L, hence			
D L =	18·188	21·428	26·27
In D C L also similar:—			
C L =	72·752	75·	78·81
R R′ = D C =	74·989	78·	83·073

Now, A B = 2 A R′ + R R′. Let B D = x. We have A B = 3 x. Hence $3x = \text{R R}' + 2\,\text{A R}'$. If in this equation we replace successively R R′ by the values found, and A R′ by $\frac{4x}{\sqrt{17}}$, $\frac{7x}{\sqrt{53}}$ and $\frac{3x}{\sqrt{10}}$, we find x = 70·76 in the square, 72·42 in the pentagon, and 75·34 in the hexagon, the corresponding fronts are therefore 212·28, 217·26, 226·02.

But if we observe that a man even kneeling would be hit by a shot passing 2 feet above the bottom of the ditch, the distance Q G may be reduced to 30 yards, and the corresponding front will be 187, 191, 199, or 200 yards in round numbers.

(95.) This *length varies* in the same ratio as *the relief*: as the relief we have adopted = (8 + 9) − 2 = 15 feet = 5 yards we have 200 = 40 × 5. It follows that for a given relief R expressed in yards, the corresponding minimum front = 40 (R − ⅔.)

As for the *maximum*, the line of defence should not exceed the effective range of musketry. Supposing a range of 300 yards; the line of defence cannot exceed 290 yards, allowing 10 yards for the thickness of parapet and the width of the ditch at the salient of the bastion.

Now, a front maximum being a figure similar to a front minimum, we can therefore make the following proportion:—

Front maximum : front minimum : : line of defence maximum : to line of defence of front minimum. Adopting the values found above, and calculating this proportion, we find successively the fronts 428, 427, 425.

With a range of 200 yards, the results would be 281, 280, 279, or nearly 300 yards.

In general, the range L being given, the maximum front corresponding to it is *very* approximatively (·47 L) − 16 yards.

For further details on the calculation of a front, see Chapter XX.

CHAPTER VI.

ACCESSORY DEFENCES.

The quality of troops greatly enhances that of the fortification they are called to defend, yet the power of resistance of a work depends chiefly upon its outline. The ground, however, may in some instances so far influence the direction and length of faces, that the deficiency of the undefended space of salients and of the dead angles cannot be obviated by a sufficient amount of flanking fire. Several accessory means have therefore been had recourse to, in order to remedy these deficiencies and to complete the defence.

SECTION I.—Artillery.

Artillery is employed only in works likely to offer a good resistance, because the loss of guns is a serious check. It may be used to oppose the artillery of the enemy, to extend the action of the intrenchment to a further range, to flank a face or a ditch, to pour round or grape shot on the ground in front of the salients.

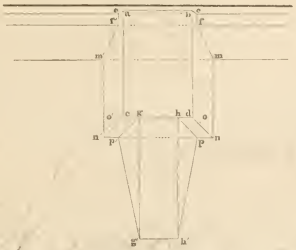
When destined to flank or to fire in a constant direction, openings called *embrasures* are made in the parapet to fire through; when intended to command a surface of ground, and to fire in various directions, the guns are mounted on a mass of earth called a platform, and are said to fire "*en barbette*" (over the parapet).

(96). *Barbette.* A field gun fires at 3 feet 6 inches above the ground; the surface of the *platform*, or its terreplein, is therefore at 3 feet 6 inches below the crest, and the gun is carried there by means of a ramp, 8 or 10 feet wide, and of a slope varying, according to circumstances, from $\frac{1}{6}$ to $\frac{1}{15}$. The terreplein necessary for the working of the gun is 15 feet wide and 24 feet long.

It would be too long to enter into the details concerning the construction of every sort of barbettes, but one example may be given to serve as a guide. Suppose the parapet to be 8 feet high, the barbette being $3\frac{1}{2}$ feet below the crest,

stands 9 inches above the banquette, therefore the foot of its interior slope will be obtained by drawing $a\,b$ parallel to the crest, and $4\frac{1}{2}$ inches from it. Making $a\,b = 15$ feet, and $a\,c = 24$ feet, the surface of the barbette is $a\,b\,c\,d$. If we imagine a slope at 45° through $b\,d$, it will intersect the banquette along $e\,f$ parallel

FIG. 210.



to and 9 inches distant from $b\,d$, and the terreplein along the parallel $m\,n$ at a distance of $4\frac{1}{2}$ feet, since the barbette is at 8 feet—3·5 feet $= 4{\cdot}5$ above ground. A slope at 45° passing through $a\,c$ will give the intersections $e'\,f'$ and $m'\,n'$, and that passing through $c\,d$ will give $n\,n'$ parallel to and at $4\frac{1}{2}$ feet from $c\,d$. Joining $b\,e$, $f\,m$, $d\,n$, $c\,n'$, $f'\,m'$, and $a\,e'$, the barbette and its slope are completed. To add the ramp, take $g\,h = 9$ or 10 feet, and with the ordinary slope of $\frac{1}{6}$ make $g\,g' = h\,h'$ = six times $4\frac{1}{2}$ feet $= 27$ feet. Take $h\,o = g'\,o' = 4\frac{1}{2}$ feet, join $g'\,o$, $h'\,o$, and $g'\,p'$, $h'\,p$.

The ramp may be constructed in the rear or on either side of the platform.

FIG. 211.

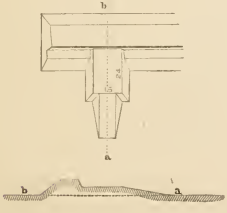
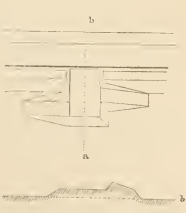


FIG. 212.



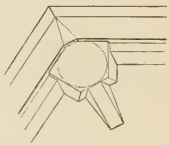
When the gun is to be placed in capital, the terreplein of the barbette is obtained

by describing, with a radius of 12 feet, a circumference tangent to the crest.

Fig. 213.

The sides are parallel to the faces of the work when the salient angle is acute, and perpendicular to them when the angle is right or obtuse.

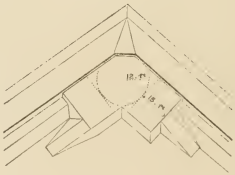
Fig. 214.



To facilitate the service of the gun, the crests at the salient are replaced by a tangent to the circumference in a direction perpendicular to the capital. The rear side of the terreplein is parallel to it.

When additional guns are required, we allow 15 feet more in the faces. And

Fig. 215.



if the barbette, at a salient, is required for two guns firing over the faces, we describe two circles with radii of 12 feet, leaving a distance of 15 feet between the centres.

Fig. 216.

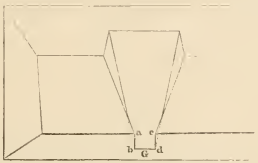
When a parapet is destined exclusively to cover a battery, the banquette is suppressed, and the *Epaulment* thus formed has only three slopes—the interior

Fig. 217.

at $\frac{1}{2}$, the superior at $\frac{1}{10}$, and the exterior at $\frac{1}{1}$. A height of $7\frac{1}{2}$ feet is sufficient.

(97). Embrasures are direct or oblique, as their direction is perpendicular or oblique to the crest.

Fig. 218.



The inside opening *a b c d*, or *neck*, is 20 inches wide for guns and 3 feet for howitzers. It is cut vertically, and is never more than 4 feet deep. The outside opening or *mouth*, as measured under the exterior crest, is equal to half the thickness of the parapet.

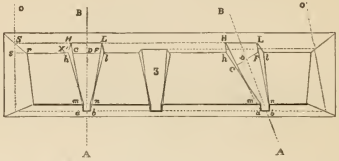
The *bottom*, or *sill*, or *sole*, slopes outwards to a point 60 yards beyond the ditch. For howitzers, the sole counterslopes, to give cover to the gunners.

The sides or *cheeks* are kept vertical at the neck, and decline from the vertical plane as they diverge outwards; this declination amounts to about 1 foot under the exterior crest.

The *genouillère* is that part of the interior slope of the parapet G, contained between the neck and the terreplein: it should always be 3 feet 6 inches.

To trace an embrasure either direct or oblique, draw the line A B along which the gun is intended to fire; at right angles to it take F D = D C = $\frac{1}{4}$ the thickness of parapet. Draw the neck *m n a b*, 20 inches wide, 4 feet deep, and by means of a profile in which O represents the object fired at, ascertain the position

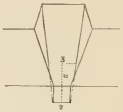
FIG. 219.



of the line S H L. Join A C and produce it to H, join *b* F and produce it to L, H L *a b* will be the sole. Taking now C *h* = F *l* = 1 foot, or, more exactly, = $\frac{1}{5}$ of *s r*, and joining *l n*, *h m*, the cheeks are formed and the embrasure is complete. The embrasure 3 is for a howitzer.

There are several other methods of tracing an embrasure. The method of General Pasley differs from the above in the construction of the sole. He makes

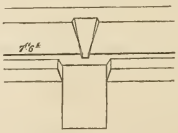
FIG. 220.



it 2 feet wide at the neck, and 3 feet wide at 5 feet from it, whatever be the thickness of the parapet.

The guns will, as for barbette, require a platform 15 feet by 24 feet.

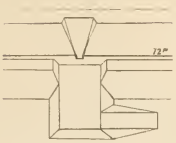
FIG. 221.



When the command of a work is greater than 7 feet 6 inches, it is necessary to

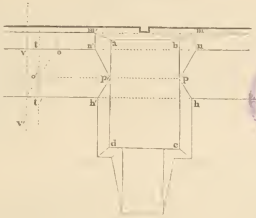
raise that platform, since the genouillère must be 3 feet 6 inches, and the neck 4 feet deep at the utmost.

Fig. 222.



The construction on paper of such a platform resembles that of a barbette: supposing the crest to be 10 feet high, the platform being $7\frac{1}{2}$ feet below it, will stand $2\frac{1}{2}$ feet above ground. Draw $a\,b$ parallel to and at $\frac{7\frac{1}{2}}{3}$ feet from the crest,

Fig. 223.



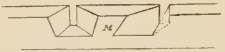
and make the square $a\,b\,c\,d$ 15 feet by 24.

Now, as the banquette is 4 feet 3 inches below the crest, it is 3 feet 3 inches above the platform; therefore draw $m\,n$, $m'\,n'$, parallel to $b\,c$, $a\,d$, and at 3 feet 3 inches therefrom; draw also $h\,e$, $h'\,e$, $e\,e'$, parallel to $b\,c$, $a\,d$, $c\,d$, and at $2\frac{1}{2}$ feet from them, and complete the ramp on the same principle as for a barbette. To finish the construction, it remains to find the intersection of the slope of banquette with the slopes at 45° passing through the sides $b\,c$ and $a\,d$. As the platform is only $2\frac{1}{2}$ feet above ground, whilst the points n, n' are at $10 - 4$ feet 3 inches, or 5 feet 9 inches above it, their intersections cannot be $n\,h$, $n'\,h'$, but will be the broken lines $n\,p\,h$, $n'\,p'\,h'$, passing through the points p, p', situated on the slope of banquette at $2\frac{1}{2}$ feet from the ground. To find the position of these points, imagine a profile: let $o\,v$ be the height of banquette above ground, draw the line $t\,t'$ parallel to $o\,v'$, and at $2\frac{1}{2}$ feet from it, it intersects $o\,q$ in o', and the line $o'\,p\,p'$

parallel to $q\,h$, determines the position of p, p'. Thus the earth will slant from mn, $m'n'$ downwards to the platform, and from pc, $p'd$ downwards to the ground.

Embrasures for guns are usually pierced 18 feet apart, but for field guns the interval may be reduced to 15 feet. This distance should be, under all circum-

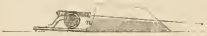
Fig. 224.



stances, such as to leave a *merlon* (M), or part of parapet intervening between two adjacent embrasures, of at least 6 feet.

(98). Both for guns firing *en barbette*, and through embrasures, it is advisable to place *platforms* or floors of wood, to prevent the wheels from sinking into the earth. These platforms should slope 6 inches from the rear, to prevent the recoil

Fig. 225.



and facilitate the running up of the guns. No slope, however, is required for the platforms of barbettes and of mortars. A square piece of timber called a *hurter*, or a fascine, prevents the wheels from touching and damaging the interior slope.

The *old pattern* platform, intended for siege guns, was 18 feet by 12. Five sleepers were buried *flush* with the ground and covered with planking. This

Fig. 226.

planking was either nailed to the sleepers, or fixed by ribands screwed or rack-lashed to the outside sleepers.

The *platform for mortars* was 7 feet 6 inches by 6 feet 6 inches, and was rendered more firm by two courses of sleepers at right angles.

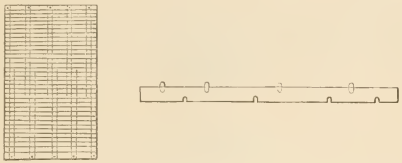
Fig. 227.

In *fortresses, the old platform* was 8 feet at the head, 14 feet at the splay or tail, and 18 feet long.

Fig. 228.

These platforms have been superseded by the *pattern of Colonel Alderson,* which can be employed for field or siege guns. The sleepers and planking consist of balks all having the same length, 9 feet, and the same scantling, 5 inches wide by 3½ inches thick, and they weigh 37 lbs. each. These balks are pierced with 8 holes, 4 on each of two opposite faces: in the holes of one face, oak-dovels are introduced

Fig. 229.



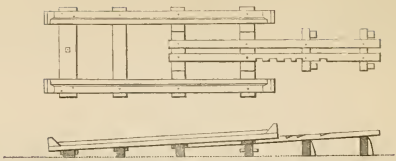
which fit into the holes of the opposite balks. The front and rear balks of the platform are secured to the sleepers by iron pins. This platform is 9 feet wide, and 15 feet long.

A mortar platform can be constructed 7 feet 6 inches by 9 feet, or 9 feet square if decking the extremities of the sleepers.

Fig. 230.

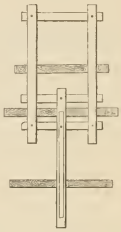
The Madras platform consists of two stout planks, 12 feet long, placed at an interval equal to the breadth of the gun carriage, and firmly secured by transoms. One or more trail pieces are bolted to the last two transoms. This platform and

Fig. 231.



the trail-piece rests on sleepers, and the whole are made to traverse on a front pivot by applying the hand-spikes to the ends of the side pieces.

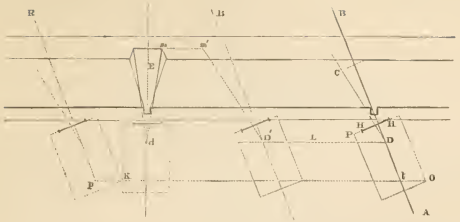
Fig. 232.



In another pattern, the side pieces being bolted to the transoms by two pivots, the traversing is limited, because these side pieces approach each other, and one pivot is preferable.

(99). Where guns have to fire in the same direction, their directing lines should be parallel, and from 18 to 15 feet apart; but when the guns must fire in different directions, a case of rare occurrence, the distance between the directing lines is so regulated as to leave a merlon of 6 feet between converging embrasures, and sufficient room for the service of the guns when the embrasures diverge. If, for instance, a gun is required to fire in a direction parallel to AB (fig. 233) on the right and left of the direct embrasure E, we trace the hurter HH at right angles to AB. Taking the point D in the same position as *d*, we draw CD as explained above. If through D we now trace DL parallel to the crest, then take $mn' = 6$ feet, and through m' draw a parallel to CD, we obtain the point D', which fixes the position of the directing line D'B', which cannot be nearer to *d* E. To place the directing line on the left, construct the terreplein PO, 24 feet by 15; through

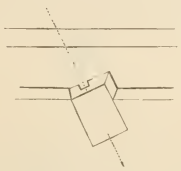
Fig. 233.



O draw a parallel OK to the crest, take K $p = t$ O, and draw pR parallel to AB.

(100). The obliquity of an embrasure rarely exceeds a few degrees, and is never above 30°. When the obliquity would prevent the muzzle of the gun from being run up through the neck, it becomes necessary to indent the interior slope, as in fig. 234. (205).

Fig. 234.



SECTION II.—Defence of the Ditch.

To defend ditches where no flanking fire can be obtained, caponiers, stockades, and galleries of counterscarp are employed, but they require some time for their construction, and are only available in localities where wood is to be found.

(101). A *caponier* is a sort of block-house built under the escarp of a face; it communicates with the interior of a work by means of a gallery (fig. 235) excavated under the parapet (fig. 236). It is often constructed at the salient of a redoubt. The ditch is enlarged before it.

Fig. 235.

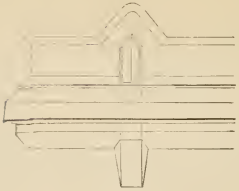


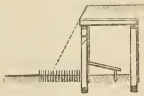
Fig 236.

(102). A *gallery of the counterscarp* is a sort of caponier buried under the counterscarp at the salient of a redoubt, or any other work possessing unflanked ditches. The counterscarp in that case is not made circular, as is usually done at

Fig. 237.

the salient angles, to diminish the déblai, but is kept parallel to the escarp This sort of work has the disadvantage of exposing its defenders to the liability of being cut off from the main force, in case the intrenchment fall into the hands of the enemy.

Fig. 238.



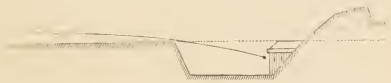
To prevent the enemy from closing upon these constructions it is usual to plant some pickets in the ground for a few feet.

(103). A *stockade* is a strong loopholed palisade (109). placed at the extremities of the faces of a redan, or at the shoulder angle of a lunette. Means should be provided for passing into the ditch.

Fig. 239.

Caponiers and stockades ought not to be exposed to the enemy's artillery; the

Fig. 240.

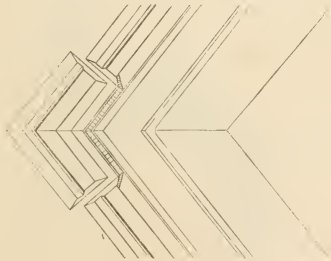


wider the ditch the greater is the danger, since a pitching fire can destroy them at a long range. Counterscarp galleries offer in this respect a better disposition.

(104). One of the defects of the outline, the dead angle in the re-entering angles, may be remedied by a simple process.

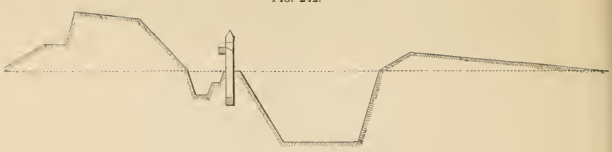
The parapet is brought back a few yards along both faces, so as to leave a berm of a few feet, to which the defenders have access by means of a small

Fig. 241.



passage. A loopholed stockade is planted on the edge of the escarp to give fire in

Fig. 242.



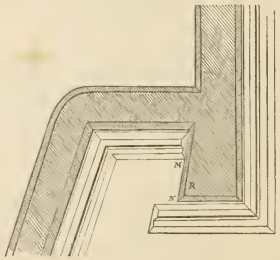
the dead angle, and the men are covered from shots that might pass through the loopholes, by sinking the terreplein of the berm and forming a little ditch.

(105). When the faces of a work are of great length, it is found advantageous to break them, as represented in the annexed diagram. This construction is

Fig. 243.

called a *retirade*. The inconvenience of a dead angle no longer exists, since there is in M N sufficient space for a few men to fire on the enemy should he attempt to venture into the re-entering angle R of the ditch.

Fig. 244.



SECTION III.—Obstacles.

(106). To hinder the approach of the enemy, to stop him under the fire of the intrenchments, to prevent his crowning the ditch, and to render the assault both a difficult and a murderous work, several accessory means (obstacles) are employed when the surrounding country offers the proper material, and when workmen are to be had. We shall successively pass these in review. Let it be premised that such obstacles cannot always be erected with regularity; an intelligent officer, when placed in a critical position, will at the moment of emergency turn to advantage the most insignificant objects. It was thus that, in 1814, when the English surprised Berg-op-zoom, the division of Skerret repulsed from the town into one of the bastions, found there heaps of palisades freshly cut, and availing itself of this simple cover, it succeeded in checking the attacks of the French for a long time, and would have maintained its position had it not been turned by the sailors, who scaled the escarp, whilst infantry renewed the attack in front.

The absence of obstructions in the unflanked ditches of fieldworks is a defect to be avoided *by all means*. At the siege of Toulon (1793) the great redoubt was carried by the French because their storming party, twice driven off, was permitted to re-form unmolested in the ditches. The redoubt of San Fernando, at Lerida (1810) was taken in a similar manner.

(107). *Palisades* are made of young trees, or of larger ones split into two or three pieces, of a triangular shape, and pointed, 10 feet long and 6 or 8 inches thick. They are placed 4 or 5 inches apart, and are buried 3 or 4 feet in the ground,

Fig. 245.

where they are fixed to a riband. Another riband placed on the inside, at 1 foot below the top, consolidates the structure. They are placed at the f ot of the

Fig. 246.

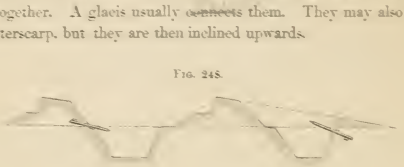
escarp, or of the counterscarp, and in the middle of the ditch: it is in this last case better to incline them outside, it being more difficult for the assailants to cut them, but in no instance should they be exposed to artillery.

They have sometimes been placed on a berm, and protected by a glacis.

FIG. 247.

108. *Fraises* are palisades placed horizontally at the crest of the escarp, or rather slightly slanting downwards: they must not project further than the foot of the escarp, in order not to afford cover. Two ribands, as is seen in the diagram, bind them together. A glacis usually connects them. They may also be placed on the counterscarp, but they are then inclined upwards.

FIG. 248.

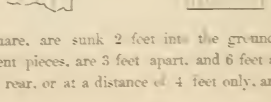


When placed on the escarp they offer a serious inconvenience. At the storming of Fort Picurina, at Padajos, in 1812, the assailants threw their ladders in the manner of bridges on the slanting stakes,—and having passed over them, scaled the parapet by resting their ladders on the step formed by these fraises.

Two carpenters can make ten palisades per hour, and three men can plant 15 yards in a day.

109. *Stockades* are palisades touching each other, and loopholed for musketry: they may be called timber walls (fig. 249): the timbers, 10 or 12 feet long, and

FIG. 249.



about 9 inches square, are sunk 2 feet into the ground. The loopholes, cut between two adjacent pieces, are 3 feet apart, and 6 feet above the ground, with a banquette in the rear, or at a distance of 4 feet only, and there is a little ditch

Fig. 250.

in front (fig. 250). The interior width of the loophole is 8 inches, the exterior 3 inches. The exterior height 22 inches, the interior 18 inches.

We have already said that they were employed to flank ditches. A *Tambour* is a stockade, redan, or lunette, erected to give flanking defence to a straight wall. In the defence of villages, houses, &c., tambours are constructed before the gates.

Fig. 251

Stockades were first employed by the Turks under the name of palankas. In the Burmese war (1825) most of the enemy's works were mere stockades.

(110). *Abattis* are made with trees, or with stout branches stripped of leaves and small branches and sharpened; they are intermingled, and their trunks well fixed in the ground by a few pickets. Their usual place is before the counterscarp, where a glacis must defend them. This obstacle is a very serious one, and we find numerous instances of its judicious selection,—at the battles of

Fig. 252.

Fribourg (1644), of Malplaquet (1709), of Fontenoy (1745), &c. In 1792, the forest of Beval, between Weissenberg and Lauterburg, was rendered literally

impenetrable by the French. In 1810, at Torres Vedras, the ravines were secured in the same manner. At Sebastopol, in 1855, the Russians greatly increased the resistance of their works by means of abattis.

In putting a village into a state of defence, the trees that border the roads are readily turned into a serious obstacle, by sawing half way through their trunks, and fixing their heads on the ground. This forms what is called an *entanglement.*

(111). *Chevaux de frise* are not so good, and require more labour; they are formed of a large joist, 10 or 12 feet long and from 6 to 9 inches square, into the sides of which are driven wooden pins, 6 feet long and 1 or 2 inches in diameter. Several are connected together by a chain. Sometimes they are

Fig. 253.

made of iron. They are chiefly employed to close the gorge of a work, to form barricades, or to arrest the inroad of cavalry.

(112). *Pickets*, from 1 to 2 inches in diameter, or thereabout, and from 2 to 3 feet long, and pointed at both ends, afford a good obstacle when placed at small distances from one another. King Henry V. won the battle of Azincourt, in 1415, in consequence of having defended his bowmen with such pickets.

Fig. 254.

In the ditch before a caponier, or in front of the counterscarp, they may become a serious impediment.

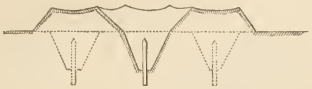
(113). *Crows' feet* at the bottom of a ditch full of water, or under an inundation, are used like pickets. They consist of stout nails 6 or 7 inches long, so constructed that one point always stands upwards. When scattered on grass

Fig. 255.

they are a serious hindrance to cavalry. The Romans, by the employment of crows' feet, were enabled to gain a complete victory over the Parthians, whose numerous cavalry would have overpowered their legions, greatly inferior in numbers. Bruce, at Bannockburn, is said to have employed them with advantage.

(114). *Military pits*, or *Trous de Loup*, placed in two or three rows in front of the counterscarp (at the salients, generally), are a formidable defence. Their depth may vary from 6 to 8 feet. A sharpened palisade is placed in the centre.

Fig. 256.



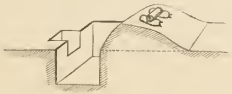
They may also to be made 2 feet deep, when there is no time at disposal. On no account should they be 4 or 5 feet deep, because the enemy might turn them into rifle pits.

Fig. 257.

The attack of the French on the Little Redan and on the works on Careening Bay, in 1855, failed because the assailing columns were thrown into considerable confusion by rows of trous-de-loup, into which men stumbled in the midst of the darkness caused by dust and smoke.

(115). *Rifle pits* are excavations 3 feet deep and 4 feet wide, affording room for two marksmen: they may be advantageously employed in front of important positions, and in the operations of a siege.

Fig. 258



(116). *Fougasses* are mines, placed at the bottom of small shafts sunk in advance of the counterscarp. They are fired from the interior of the work, by means of a powder-hose brought along one side of the shaft, and carried through 6 inches (fig. 259) below the ground: the explosion breaks the ground, and

Fig. 259.

throws the assailing columns into confusion. But they are of difficult construction. Their distance from the counterscarp ought to be about twice their depth, otherwise the explosion would destroy this scarp, the crater of explosion being of a diameter equal to $1\frac{1}{2}$ the depth. (See 250, 258).

Shell fougasses are formed of shells buried underground, either singly or in rows: generally they are placed in double boxes, the fuses passing into a compartment full of powder, with which the hose communicates. At Badajos the French buried rows or chaplets of these shells along the counterscarp of the breached faces.

Fig. 260.

A *Stone Fougasse* is of easier execution. It consists of an excavation 5 or 6 feet deep, the axis of which makes an angle of 45° with the horizon. The powder is placed at the bottom of it, and covered with a strong shield of wood at right angles to the axis, communicating with the work by means of a hose.

Fig. 261.

It is then filled up with stones, pebbles, &c., and the upper part covered in with turf. A fougasse 6 yards wide and 5 deep, loaded with 50lbs. of powder and 4 cubic yards of stones, when exploding scatters the material over a square 55 yards wide. At Gibraltar (1782) the defenders had recourse to them frequently.

Fougasses are sometimes formed under works for the purpose of destroying them when abandoned. In this case they must be laid 6 or 7 feet below the centre of the parapet before the rampart is built. They may also be laid under the terreplein, as the Russians did at Sebastopol in their redans.

(117). *Inundations.*—When a stream is in the vicinity of a work, an inundation may be formed by constructing dams across the valley; the water thus swells above the banks and overflows the country. To be a serious obstacle, it should be deeper than 5 feet; and when this depth cannot be attained, holes should be excavated here and there, and crows' feet employed, to render access difficult.

The up-side of a dam is inclined at $\frac{1}{2}$, the down-side at $\frac{1}{4}$ or even at $\frac{1}{3}$, when there are 6 feet of water on that side: with a steeper slope, the weight and friction of the liquid would soon injure the work. The top, or crown, is horizontal, and 4 or 5 feet above the level of the water up the stream. The thickness at the top is 5 feet, or double that dimension when it is exposed to artillery. It is advisable, in order to protect it against that fire, to trace the dam obliquely to the ground which the enemy can occupy, the upside facing towards that direction, because the down side is not so much covered with water.

Fig. 262.

The material employed for the construction, is extracted from a ditch excavated at about 20 yards below it, but if the earth found on the spot does not bind well, some clay or puddling must be procured to form the centre of the dam, so as to prevent filtration.

The dam is constructed by horizontal layers, an opening being left in the middle to let the stream pass: when both extremities are completed, a belt of sods is formed in front of the opening, and the work is rapidly finished.

When several dams are constructed, the distances at which they are placed apart, depend upon the inclination of the valley: they are calculated so as to allow a depth of at least 5 feet at the foot of the down side.

They should be defended by works or batteries in the rear. Waste weirs are

Fig. 263.

constructed in each dam to let the superfluous water run over into the adjoining inundation, but as it would rapidly injure the dam if it were allowed to run over its earthern slopes, the sides and bottoms of the weir are strongly riveted with

fascines or planks. Other fascines are also laid down in the bed of the lower inundation to prevent the formation of pits. If the dam serves as a communication, a wooden bridge is thrown over the weir. Sluices may also be employed simultaneously with the weirs. (381.)

(118). An attempt to form an inundation, should not be made hastily: we must first ascertain whether the soil is suitable, some soils would let all the water soak through in 24 hours; next, we must calculate the time necessary to effect the required inundation. Evaporation and filtration both tend to diminish the depth, and when the supply of water is small, they may become prejudicial. The quantity of water V furnished per second by a stream, is found by the formula of Prony. $V = l,\ h,\ u;\ u = -\cdot 07 + \sqrt{\cdot 005 + 3233\,\frac{lhi}{l + 2h}}$, in which l represents the width of bed, h the mean depth, u the mean velocity per second, i the fall.

The volume of water may also be calculated by measuring the section of the bed, and multiplying it by the mean velocity. The mean velocity V′ is given by the formula of Dubuat. $V' = \frac{V + (\sqrt{V} - 1)^2}{2}$ in which V represents, in inches, the velocity at the surface.

The evaporation varies from $\frac{1}{16}$ to $\frac{1}{25}$ inch per day, but in windy days and in summer it is far more. The filtration may be reckoned at 2 inches per 24 hours.

Water may also be employed to fill the ditches of field-works; but this sort of defence fails in winter, and becomes dangerous; and when a garrison has to remain a long time in an inundated country, fever does more mischief than the enemy. In têtes-de-pont however, we often make use of it.

CHAPTER VIII.

DETERMINATION OF THE PROFILE OF FIELD WORKS.

SECTION I.—Defilade.

(119). When a field-work is to be erected in the vicinity of a height that commands it within the range of musketry, it becomes necessary to conceal its interior from the plunging fire of the enemy. This is done sometimes by modifying the outline; otherwise, we arrive at the solution of the question by altering the relief—either raising the parapet or depressing the terreplein—an operation called *Defilade.*

This is a very important problem, inasmuch as the very purpose for which the fortification is made is not obtained if the men are not covered: they must move without being seen on the banquette and the terreplein.

In open works, the gorge is the limit to which the defilade must cover the garrison; and in lines, this limit must extend as far as 20 yards in rear of the innermost tracing, because much space is required for the large bodies generally occupying these works.

Let us suppose H a height, within reach of musketry of a lunette, G a point of the gorge, and A the salient.

Fig. 264.

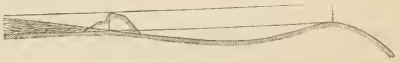
By the line of gorge and the commanding point O, we imagine a plane called the *Plane of Site,* the trace of which is here represented by the line OG. Parallel to and 8 feet above it, another plane, the trace of which is here represented by BC, is called the *Plane of Defilade.*

If the crests of the work are kept in this plane, the terreplein and the gorge will evidently be covered.

The increase of relief must not exceed 4 feet, otherwise another position or another outline must be selected for the intrenchment.

The defilade can also be effected by sinking the terreplein and keeping it parallel to the plane of defilade.

Fig. 265.



In such case the ditch becomes smaller, or a glacis must be constructed to get rid of the surplus of earth. The first method is preferred in the field, when time is a matter of importance.

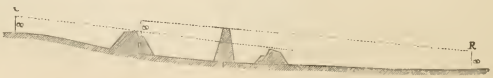
If the work is to be defiladed from artillery instead of musketry, the plane of defilade is 4 feet only above the plane of site. 1000 yards is generally the greatest distance from which we defilade a work from artillery fire.

The great difficulty of defilade consists in the proper selection of the plane of site; this plane should pass over all the commanding ground, therefore it is not the highest point, but that point whose apparent elevation is the greatest, which the plane of site should pass through.

Fig. 266.

(120). When the commanding ground is in front of an open work, there is no difficulty in defilading its terreplein, or even a larger zone of ground in its rear, as is the case with têtes-de-pont, when the bridge or dam they protect must be concealed from direct view. But when the work is enclosed, the problem is more difficult. It is clear that in raising the part of parapet nearest to the height, the men mounted on its banquette become exposed to the reverse fire directed over that part of parapet which is more remote from the commanding ground. Thus the men standing on the banquette *a*, are exposed to the fire directed from R, and the more so in proportion as the parapet is made higher. In this case, the most advantageous that may occur for an enclosed work, the terreplein is defiladed, yet it is necessary to erect a traverse or *parados*, to cover the men from

Fig. 267.



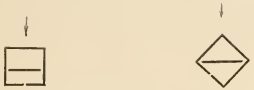
the reverse fire directed from R, (C and R are supposed to be at the limit from which we must defilade,) to 8 feet above the banquette *a*. (134.)

This parados would not always be sufficient, as in the following case where the men on banquette *a*, being covered from reverse fire from R, those on banquette *b*, are exposed to reverse fire from *c*. Here the parados must be raised up to *m*.

Fig. 268.

Hence, to defilade an enclosed work, it is indispensable to construct a traverse or parados across its terreplein, when the work has the commanding height in front, or is on the side of a hill.

Fig. 269.



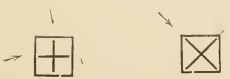
(121). Should the commanding height be situated on the right or left of *open* works (fig. 270), a similar disadvantage attends them, and a parados is also necessary; and if there is a height on both sides as well (fig. 271), a traverse must be erected, which will cover both banquettes.

Fig. 270.

Fig. 271.

In the case of an enclosed work, it is a matter of the utmost difficulty, and whenever the commanding ground is on the front and on the side at the same

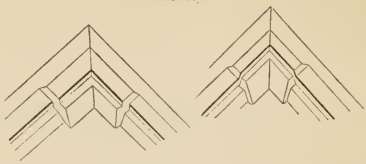
Fig. 272.



time, two traverses across the terreplein must be constructed. Should it be commanded in all directions, it would no longer be possible to defilade it.

(122). When the ground only rises slightly in front of a salient, a mere increase of relief, 2 or 3 feet, on a length from 4 to 5 feet of the parapet, called

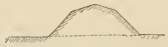
Fig. 273.



a *bonnet*, is sufficient to prevent the enfilade. Bonnets are sometimes employed along faces, between guns firing en barbette.

Traverses with fascine or gabion revetments fulfil the same purpose. Although these parados greatly increase the labour, and render the communication difficult, still, when time is abundant, they are most valuable. Passages are cut through them to enable the garrison to pass freely from one part to another, and they form a good shelter for powder magazines. Their profile varies: the thickness at the

Fig. 274.

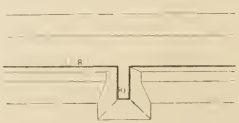


top should be 3 feet to resist musketry, or from 6 to 9 to resist artillery. This top is either horizontal or inclined in a ridge to carry off water. The slopes on both sides are at $\frac{1}{1}$. When there is not sufficient room in the terreplein for a traverse of this kind, a mask of timber and earth may be substituted for it.

Fig. 275.

To protect the banquette from ricochet fire, small traverses of this description

Fig. 276.



are sometimes constructed. As a drawing exercise, we give the plans of two parados, one along a face (fig. 277), the other at a salient (fig. 278); their top is horizontal, and their slopes at $\frac{1}{1}$.

Fig. 277.

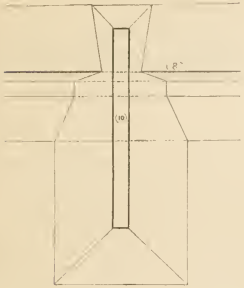
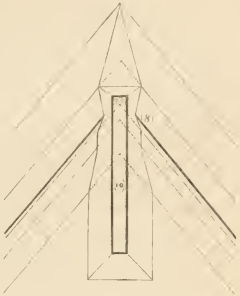


Fig. 278.



We should avoid the necessity of having to defilade fieldworks; but if seen from the plain, or from commanding points, a remedy must be found in simple methods: high parapets should be avoided, and traverses made very sparingly. The slopes of the ground itself should serve to defilade in the field whenever possible.

It is a fact that defilade is but a poor remedy for the defects arising from a bad position; it is very seldom that a fieldwork can be properly defiladed; and even when the terreplein is covered, the banquettes are much exposed, and the work is unfit to make a good defence.

SECTION II.—Calculation of the Déblai and Remblai.

(123). The earth extracted from the ditch must be in sufficient quantity to construct the parapet and its slopes. In permanent fortification, when time and means of transport are at our disposal, we may deviate from this rule; but in the field when we are obliged to spare time and reduce as much as possible the number of workmen, the equality between the déblai and remblai is indispensable for every part of the work, nay, for every face. Even then, if the faces are long, this condition is scarcely sufficient, since in defiladed works, where the covering mass has a greater thickness at the salients, there will be great difficulty in transporting

with shovels the excess of earth from the salient to the other extremity. To solve the problem completely, equality should exist for every part of each face, but this would lead to inconvenience as will hereafter be seen, and we content ourselves with establishing equality for every face.

For works not defiladed, and having therefore their crest horizontal, we employ the following method, whenever expedition is required.

We suppose the parapet and the ditch to have the same length, their volumes will therefore be equal if their profiles are equal, and the problem is simplified into this: knowing the area of the profile of the covering mass, to calculate the dimensions of the ditch so as to make the surface of its section equal to that of the remblai.

Let S represent the area of the section of the remblai. When earth is excavated, it increases in bulk, and whatever care be taken in ramming it in, the volume it occupies in the remblai will be greater than the space it filled in the deblai; this increase of bulk, called *foisonnement*, is $\frac{1}{8}$ in strong soil, $\frac{1}{12}$ in ordinary soil, and $\frac{1}{20}$ in sand. Represent it by $\frac{1}{f}$, and let the area of the profile of the ditch $= S'$, we should have $S = S' + \frac{S'}{f}$, therefore $S' = \frac{S.f}{1+f}$.

FIG. 279.

If we take for an example, a parapet 12 feet thick with a command of 8 feet, its area is calculated by decomposing it into three trapezoids and one triangle.

Trapezoid ABCD $= \frac{(3 + 7{\cdot}5 + 3)}{2} \times 3{\cdot}75 = 25{\cdot}31$ square feet.

Ditto . . CDLH $= \frac{(3{\cdot}75 + 8)}{2} \times 1{\cdot}43 = 8{\cdot}22$ square feet.

Ditto . . HLPQ $= \frac{(8 + 6)}{2} \times 12 = 84$ square feet.

Triangle . PQS $= \frac{(6 \times 6)}{2} = 18$ square feet.

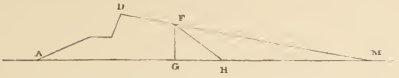
S . . . . . $= 135{\cdot}53$ square feet.

and in assuming a foisonnement $= \frac{1}{9}$, the surface of the profile of the ditch will be

$\frac{8}{9}$ S $= 120{\cdot}47$.

This calculation of the area of the parapet may be simplified since the surface

FIG. 280.



A D F M remains constant, whatever be the thickness, and is equal to 225·53 square feet, with a banquette of 3 feet, and to 231·15 for a banquette 4 feet 6 inches wide. The area required is equal to that surface minus the triangle F H M.

But $FHM = FGM - FGH$; $FGM = \frac{GM}{2} \times FG = \frac{6\,FG.FG}{2} = \frac{6\,FG^2}{2}$;

and $FGH = \frac{GH}{2} \times FG = \frac{\overline{FG}^2}{2}$. Therefore $FHM = \frac{5}{2}\overline{FG}^2$.

Hence the total area of the profile is given by the formula $S = 225{\cdot}53 - \frac{5\,\overline{FG}^2}{2}$. FG being at once found by subtracting a sixth of the thickness of the parapet from the command 8 feet. In our case, $S = 225{\cdot}53 - \frac{5}{2}(6)^2 = 135{\cdot}53$.

This calculation is not long, but for greater rapidity, the following rules are given in the Sandhurst course: add the bases of the superior and exterior slopes, and multiply by the command; or to three halves of the command add $\frac{2}{5}$ of the thickness, subtract $4\frac{1}{2}$, and multiply by the command.

The calculation of the area of the profile may be simplified by a geometrical construction, which consists in drawing the profile on a large scale, say, 10 feet to the inch, and making a triangle equal to it.

Suppose the parapet 8 feet high, and 12 feet thick. Draw the profile A B C D E H. Join C A, draw B M parallel to it, and join C M.

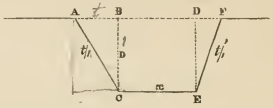
FIG. 281.

The triangles M B C, M B A, being on the same base M B, and between the same parallels are equal, and as the part M O B is common to both, the remainder B O C = M O A; therefore the the two lines C B, B A may be replaced by C M. Again, join D H, draw E L parallel to it, and join D L: for the same reason as before the two lines D E, E H may be replaced by D L. Lastly, join C L, draw

D N parallel to it, and join C N. This line replaces C D, D L, and the triangle M C N is equal to the given profile. Measuring M N with the scale, we find it equal to 33·5 feet, therefore the area of the profile $= \frac{33{\cdot}5 \times 8}{2} = 134$ square feet.

(124). Passing to the ditch, we observe that the slopes of the scarps are given by the nature of the soil (52), and that two dimensions, *i. e.* the width and the depth, can vary. In general we assume the depth, and calculate the width. Let D be the depth, x the width at bottom, $\frac{t}{1}$ the slope of the escarp, $\frac{t'}{1}$ that of the counterscarp.

FIG. 282.

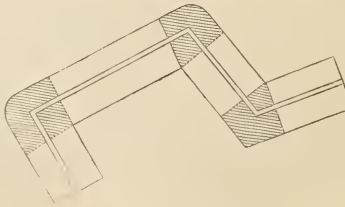


The area $S' = A B C + D E F + B D C E$; but $A B C = \frac{A B . B C}{2} = \frac{D^2}{2t}$ $D E F = \frac{D^2}{2t'}$, and $B D C E = D x$, therefore $S' = D x + \frac{D^2}{2}\left(\frac{1}{t} + \frac{1}{t'}\right)$, a simple equation which gives the value of CE. In our example, assuming a depth of 9 feet, and the slopes $\frac{t}{1} = \frac{2}{1}$, $\frac{t'}{1} = \frac{3}{1}$, we have $120{\cdot}47 = 9x + \frac{81}{2}\left(\frac{1}{2} + \frac{1}{3}\right) = 9x + 33{\cdot}75$, hence $x = 9{\cdot}63$.

If instead of adopting a certain depth we had assumed the width w, the former equation becomes $S' = wx + \frac{x^2}{2}\left(\frac{1}{t} + \frac{1}{t'}\right)$, a quadratic equation.

(125). This is only an approximate method of calculating the deblai, as may be seen by the diagram. There is equality along the faces, but at the salients there

FIG. 283.



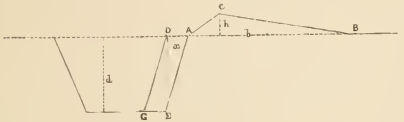
is excess in the deblai, and at the re-entering angles a deficiency which does not compensate for it, the excess being always greater than the deficiency. In order to remedy this, the workmen whilst excavating are directed to throw the earth obliquely towards that part of the remblai where it is wanted; and to get rid of the surplus of earth either a benette is constructed at the salient, or the material is thrown up into a glacis.

In a tenaille where there is but one re-entering angle, the deficiency is supplied by cutting into the angle of the counterscarp, but this method has the inconvenience of increasing the area of the dead angle.

FIG. 284.

(126). Should a glacis be required, the ditch is first calculated as above, and to obtain the increase of width x necessary to furnish earth, we have, in repre-

FIG. 285.



senting by b and h the base and height of this glacis, $x = \frac{b\,h\,f}{2\,d\,(1+f)}$, very approximately. To prove this formula, let us observe, that since rectangle D A G E must be equal to A C B, we have in calling the depth d, $x.d = \frac{b\,h}{2}$, and with the foisonnement $\frac{1}{f}$, $x\,d\,(1+\frac{1}{f}) = \frac{b\,h}{2}$, hence $x = \frac{b\,h\,f}{2\,d\,(1+f)}$.

For a traverse, the earth is either extracted from the nearest ditch, and enters into the calculation, or it is neglected and the remblai taken from a ditch excavated in the terreplein—either from a ditch of the usual form, or from an excavation having a gentle slope, so as to form part of the terreplein itself. When the defilade is practised by sinking the terreplein, the material is at once obtained.

In the case of works flanked by others, ramps are frequently cut to unmask the ditch. In this as well as in other circumstances when the ditch proves in-

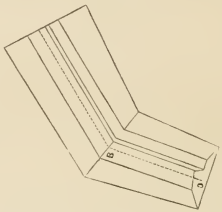
sufficient for the defence, its width is increased, and the excess of earth thrown up into a glacis.

When the work is defiladed by an increase of command at the salients, it becomes necessary to obtain the mean profile: this is done by calculating the area S_1 of the profile at the salient, and that of S_2 of the extremity of the face, when $S = \frac{S_1 + S_2}{2}$.

For field purposes the method above explained is generally found sufficient. When, however, there is plenty of time to prepare a work, a plan is drawn and more exact methods are resorted to, in order to obtain the volume of the remblai, especially when the works are defiladed.

(127). *Centrobarique method.* A section is made in the middle of each face, and its area is calculated as above. This mean surface is multiplied by the mean line *o* B, which is the path of the centres of gravity of the various sections; the product gives the volume. This line *o* B may be measured at the scale of the plan, and when the work is regular, this method is rapid.

Fig 286.



(128). *Method of the prisms.*—But when the work contains barbettes, it is preferable to divide the surface of the ground occupied by the remblai into triangular parts, more or less wide as the ground is more or less uneven, endeavouring also to place the sides of these triangles under the projections of the various crests. The triangles thus become the projection of vertical prisms contained between the ground and the planes of the remblai. The solid content of each prism is equal to the area of the base or projection, multiplied by a third of the sum of its three vertical edges. The dimensions of the triangles are measured by means of the scale of the drawing, the various altitudes being also indicated by the plan. The sum of all the prisms gives the solid content of the work.

These two methods may occasionally be employed together: thus in defiladed

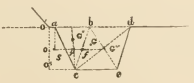
works, where the ground is rather uneven, the volume contained between the plane of site and the ground is measured by the method of prisms, and that of the mass above by the centrobarique process.

(129). Supposing that by either of these methods the volume V of the remblai has been found, that of the ditch V′ is equal to $\frac{f}{1+f}$ V. The mean section of the ditch multiplied by its length must be equal to V′, but the dimensions of the ditch are unknown. Let P represent the area of its mean profile, and L its length, PL = V′. Now, L does not vary much when the ditch is kept within the usual limits of 8 and 12 feet; the width at the top is never less than 12 feet, and is seldom found greater than 20 feet. We can therefore select approximately the centre of gravity of a provisional profile, and trace the line L parallel to the foot of the exterior slope, say at about 9 or 10 feet. The length L is measured with the scale of the drawing, and by P L = V′ we find P. With this value we can calculate the dimensions of the ditch as before, $P = Dx + \frac{D^2}{2}\left(\frac{1}{t}+\frac{1}{t'}\right)$.

If the centre of gravity differs much from the position selected, we modify it and begin a fresh calculation, or we add or subtract from this ditch a certain prism, the width of which is given by $\frac{D}{L}$, D being the difference between the volume of the provisional ditch and V′.

(130). This process is frequently employed, but there is another more exact which may be pointed out. Let V be the solid content of the face A B. The volume of the ditch, whose depth is *d*, must be equal to area *a b c d e* (fig. 287), multiplied by the line *g c* passing through its centre of gravity G (fig. 288). Let us divide the solid content of the ditch into two parts: the first we may imagine to be generated by the triangle *a b c*, the second by the parallelogram *b c d e*. The first volume

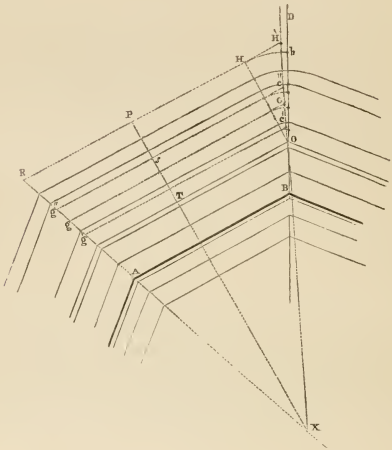
Fig. 287.



we know at once, since it is equal to the area of *a b c*, multiplied by the path *g′ c′*, let this volume increased by $\frac{1}{f}$ be represented by *v*. We do not know the second volume, as the side *c e* is the unknown *x* of our problem. Let G″ be the centre of gravity of the parallelogram *b c e d*, situated at the intersection of the diagonals, and G the centre of gravity of the whole profile *a c e d*. The distance O G″ be-

tween G″ and the vertical passing through the foot of the exterior slope = $G''f + rf + rs + so$, and in calling b the width of the berm, $G''O = \frac{x}{2} + \frac{1}{2}\left(\frac{d}{t} + \frac{d}{t'}\right) + \frac{d}{t} + b = b + \frac{t + 2t'}{2\,tt'} d + \frac{x}{2}$.

FIG. 288.



Now, the circles described from the centre O and contained in the angle D O H of the right-angled triangle D O H, have for the limit of their development the line O H′, obtained by describing an arc H h with any radius O H, and carrying the length of that arc on H H′. The line passing through the centre of gravity G″ will be limited in C″. Producing H′ O and g A till they meet in x, and drawing X P perpendicular to H H′, the similar triangles thus formed give X P : X s : : R H′ : g'' C″. The dimensions X P, R H′ are measured with the scale of the plan as for X s, it is equal to X T + T S, of which X T is also given by the plan, and T S already found $= b + \frac{t + 2\,t'}{2\,t\,t'}\,d + \frac{x}{2}$. Therefore $g''\,C'' = \frac{X\,s\,.\,R\,H'}{X\,P}$. Putting H′ R $= m$, X P $= m'$, X T $= m''$, we have $g''C'' = \frac{m}{m'}\Big(m'' +$

$b + \frac{t+t'}{2\,t\,t'}\,d + \frac{x}{2}\Big) = a$ for instance. The area of the parallelogram $b\,c\,d\,e$ including foisonnement is $\frac{d\,x}{2}\left(\frac{f+1}{f}\right)$, therefore the volume required is $\frac{a\,d\,x}{2}\left(\frac{f+1}{f}\right)$; and the total volume $V = v + \frac{a\,d\,x}{2}\left(\frac{f+1}{f}\right)$, a quadratic equation.

(131). In all that precedes, we have adopted a mean profile for the whole ditch, therefore there will be too much deblai at the extremity of the faces and not enough at the salients. The excess equally balances the deficiency on paper; but in practice the earth must be transported where it is wanted; and this transport, which the calculation of deblai and remblai is destined to avoid, reappears.

To obviate this, the workmen when excavating throw the earth obliquely along the plane of site, every squad passing it to the next. Time is thus saved, since all the men contribute to the task; but impediments are unavoidable, and it requires a great number of workmen.

The only means to avoid this would be to have a ditch with a variable section. If P' and P'' are the profiles of the ditch at each extremity, S', S'' the corresponding sections of the remblai, $P' : P'' :: S' : S''$, therefore $P' : \frac{P'+P''}{2} :: S' : \frac{S'+S''}{2}$, but $\frac{P'+P''}{2}$ is the mean section P, which is known, and $\frac{S'+S''}{2}$ is also the mean section S of the remblai, therefore $P' : P :: S' : S$, hence $P' = \frac{P\,S'}{S}$, and $P'' = \frac{P\,S''}{S}$. In this way we perform the necessary labour only; but the workmen at one extremity will have finished before those of the other end, and it is, for this reason, preferable to adopt a constant profile for the ditch.

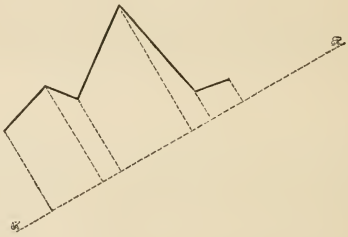
CHAPTER VIII.

EXECUTION OF FIELD WORKS.

SECTION I.—Construction.

(132). The outline and relief of a work having been selected, the first step to take in the construction is the *tracing* of the subcrest on the ground. If the work has been prepared on paper for some combination of defence, its proper position on the ground must be found. This is done by selecting a base line passing through two points of the ground, the projections of which are fixed in the plan, and setting off the lengths of the perpendiculars measured on the plan (fig. 289).

Fig. 289.



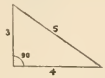
When there is no such plan, and when the work is to be thrown up on a given spot, it is understood that we direct its salients towards points difficult of access, and that we otherwise select the most advantageous site.

The faces are marked by little pickets 18 inches long, placed at the angles, and they are either traced with a pickaxe, or, what is better, by means of a piece of tape. As for the angles, triangles of cord are found more expeditious than

instruments, such as sextant, &c. Three bits of cord of equal length knotted together, and stretched, form an equilateral triangle, and give an angle of 60° (fig. 290). Three pieces of the respective lengths, 3, 4, 5, form a right-angled triangle (fig. 291).

Fig. 290.

Fig. 291.



To trace on the ground a perpendicular to a line, from a point in the same, measure equal distances on opposite sides: drive pickets at each extremity, and by fixing a piece of rope at each of them, and doubling it, the vertex belongs to the perpendicular.

To drop a perpendicular on a line from a point without, drive a picket at the point, fasten to it a piece of rope sufficiently long, and in keeping it stretched, move round until the other end of the rope intersects the line on right and left. Half the distance between the two points of intersection is the extremity of the perpendicular.

(133). The tracing of open works and bastioned fronts presents no difficulty, but for redoubts or star-forts a few words are necessary. To trace a polygon of five, six, seven, or eight sides, form an isosceles triangle of cord, having for base $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, and $\frac{1}{8}$ of the whole perimeter, and for the other two equal sides a length of $\frac{3}{4}\frac{3}{0}$, $\frac{4}{4}\frac{0}{0}$, $\frac{4}{4}\frac{6}{0}$, or $\frac{5}{4}\frac{3}{0}$ of the base. This triangle being stretched and carried, five, six, seven or eight times, as the case requires, will give the polygon.

Fig. 292.

Fig. 293.

Fig. 294.

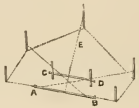
Fig. 295.

For star-forts of six, seven, or eight salients, trace as above a polygon of six, seven, or eight sides, and on each side describe an equilateral triangle. The sides of these polygons should of course respectively be equal to $\frac{1}{1\cdot2}$, $\frac{1}{1\cdot4}$, and $\frac{1}{1\cdot6}$ of the whole perimeter of the star-fort.

(134). The projection of the superior crest being traced, the next step is the *defilading* of the work. The pickets planted at the various angles of the tracing are replaced by vertical poles, and the operation proceeds as follows:—

For open works, a rope is stretched along the gorge on the ground, and a rule of wood is fixed along it, so as to be very nearly on the surface of the ground. At 8 or 10 yards in front of this line two poles are planted vertically, and a second rule of wood is moved along it by two men facing the gorge. An officer lies on the ground in the rear of the gorge, and places his eye close to rule A B, and commands the men who hold the rule C D, to raise or lower it, until

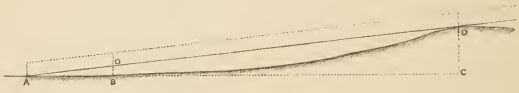
Fig. 296.



he sees the upper edge touching the commanding ground. The line C D is kept in the same plane with A B by a fourth person, who, turning his back to the commanding ground, by signs, causes those who hold the rule C D to lower or raise one extremity, as the case requires. The rule C D being nailed on the poles, when the plane of sight is determined, the officer observes where the line of sight across the two lines intersects the poles planted at each angle, a man marking these points. By measuring eight feet above them, the command is obtained, and the poles are cut at the proper height.

If the altitude D C of the commanding ground, and its distance A C to the gorge of the work are known, we can at once find the increase of command O B at the salient B, by a proportion A C : C D : : A B : B O, and B O + 8 feet will be the command.

Fig 297.



If the commanding height, instead of being in front of the salient, is on the side of a face, it is usual to make the plane of site pass only through the furthest extremity A of the line of gorge, because the process explained above would give too great a relief. In that case a triangle made of smooth lath, each of whose sides is from 4 to 5 feet long, is placed with its vertex on A, and is made to revolve about it until an officer lying on the ground can see its surface tangent to the commanding ground. A parados is necessary to cover the men on the banquette

of the face A C (fig. 298); and to reduce its height it is erected as near to that face as is convenient.

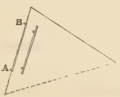
Fig. 298.

When, instead of one height there are two in front of the salient, the plane of site must be tangent to both, and cannot, therefore, contain also the line of gorge: it is also necessary to make it pass only through one point of it. In general a single plane of defilade will give too great a command, in which case we take two planes of site, and defilade separately each face from the height in front of it, and erect a parados to avoid the reverse fire.

(135). This method of proceeding is called defilading by the plane of site in opposition to a less expeditious way called defilading by the plane of defilade, which consists in sending a man to the commanding ground to plant a stick 8 feet high; a rope is then fixed on two pickets at 8 feet above the gorge, and the visual rays passing along this rope to the top of the stick being in the plane of defilade intersect the various poles of the tracing at the required heights.

(136). It is not found advantageous in the field to defilade a work by sinking the terreplein, because the earth thus obtained forming part of the remblai, the ditch destined to furnish the remainder would be too small, and would require to be widened, the excess of earth forming a glacis; but if this method is not employed alone, it is often had recourse to in combination with the other. This happens when the command found with the plane of site is too great. In this case a first plane of site passing below the commanding ground is selected, and to complete the defilade by the excavation of the terreplein, a rule A B is fixed

Fig. 299.



to two pickets on the projection of the crest with its superior edge in the first plane of site. A second rule is placed in rear along two poles, and the observer moves it until its superior edge, coinciding with A B, touches the commanding ground. It is then nailed to the poles, and by its position it fixes the plane of the terreplein.

(137). In regard to enclosed works, a redoubt for instance, the process described, No. 135, may be applied, a man being sent to the dangerous points with a pole 8 feet high; or an officer raises himself 8 feet above any convenient point of the terreplein, and a man placed on the tracing of a face, holds a measuring rod between the officer and the hill. A visual ray directed by the officer to a point estimated 8 feet above the commanding ground will intersect the rod at the point where the crest of the parapet must pass. This is repeated on the opposite face. The parados will be erected where the officer stood, its command being determined by visual rays passing 8 feet above the commanding height opposite, and 8 feet above the banquette of the face most remote from it. However, much trouble is spared by merely making the parados 3 feet higher than the parapet, as it is a command quite sufficient in most cases.

(138). The defilading terminated, we pass to the *profiling*.

Fig. 301.

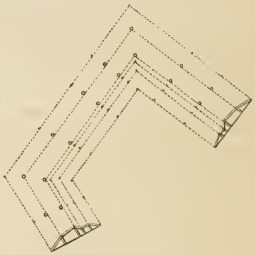
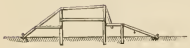


Fig. 300.



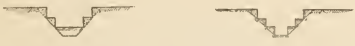
To show the dimensions of the remblai, and to guide the workmen, right profiles (fig. 300) made with slips of deal are constructed along every face, some 10 yards apart. At the salient and re-entering angles oblique profiles are also erected, the position of their vertical poles being obtained (fig. 301) by the intersection of the lines passing through the corresponding poles in the contiguous faces; the slips marking the slopes are fixed and adjusted with those of the faces, so as to form regular planes. Similar constructions are made for barbettes and traverses.

(139). The ditch cannot be excavated at once in its proper shape, but it is dug by vertical layers of about 3 feet. If the lines A B represent the width of

Fig. 302.

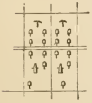
the ditch at the top, we first trace the lines C C parallel to A B, and at a distance regulated by the slopes of the scarps: in this example both the escarp and counterscarp being at $\frac{1}{4}$, the distance between A B and C C will be 3 feet. The working party excavates vertically between C C, and when the depth reaches 3 feet, new lines are traced (fig. 302) and so on. When the required depth is arrived at, the steps of the counterscarp are first cut away, then those of the escarp.

Fig. 303.



(140). *Division of Labour.*—The workmen are divided into small squads, occupying about four or five yards on the deblai, according to the nature of the soil and the depth at which they are working, a greater number being necessary for a greater depth. Ten men form a good squad.

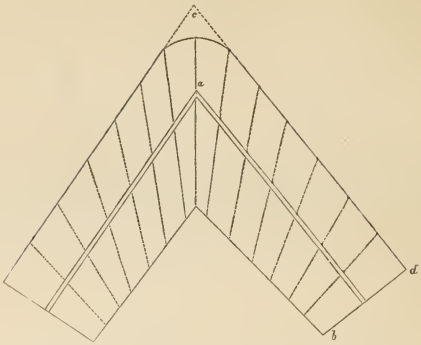
Fig. 304.



A pickaxe breaks the ground, two shovels (fig. 304) following, throw the earth towards the scarp, whence two other shovels throw it up the berm; from thence again two shovels throw it upon the profile. The remblai rises horizontally, two shovels equalizing the earth, and one man ramming it in. When the soil is hard, two pick-axes are necessary to occupy the shovels, and when it is very loose, one pick-axe may require three shovels to clear the deblai. As a rule, the diggers should not be nearer to one another than 4½ feet.

In order to place the squads on the ground, the line *a b* which represents the top of the escarp is divided into parts of four or five yards, and *c d*, which represents the counterscarp, into the same number of equal parts. In joining the points of division, the position of each squad is determined. In defiladed works the men nearest to the gorge will have completed their task sooner than those at the salients, but when they have finished their task, they are employed to prepare the obstacles, &c.

Fig. 305.



At the rate we have supposed, there will be wanted about two men per running yard, and as the garrison is generally calculated at the rate of two men per yard and a reserve, there will be a sufficient number of hands.

Another method of dividing the labour, is preferable for works of small profile. The workmen are told into two parties: the first have a shovel and a pick-axe each; half of the second party a shovel and a rammer each, and the other half a shovel only. This arrangement permits the first party, whose work is the hardest, to change with the second without confusion, since their number is equal. The deblai is then divided into rectangles 8 yards wide, and 16 men are allowed for each. The pick-axes, 8 in number, will be in the ditch, the odd numbers near the berm excavating towards the counterscarp, the even ones in the middle: these also excavate towards the counterscarp, and when they reach it they move to the berm, and proceed as the odd numbers did, so that there will always be 6 feet distance between the pick-axes. The shovels are on the berm, the shovelled rammers on the parapet. In this method there will still be two men per running yard of parapet.

Fig. 306.

When the remblai is nearly completed, fine earth is reserved for the superior part of the parapet, to avoid splinters. The slopes steeper than $\frac{3}{4}$, are supported by revetments, the others are pared when the work is completed. The terreplein, if necessary, is drained.

(141). The men composing a detachment are usually expected to throw up

their intrenchments themselves; in some few instances, workmen are taken from among the inhabitants. It is then better to pay them by the task instead of by the day, and to fix the task and the price of labour. An officer will find it the best plan to employ at first a few men, and to pay them well for a day or two's work: it will soon regulate the daily task.

Field-works are often thrown up in a great hurry, and care must be taken not to begin a work unless there is a certainty of having it completed in due time. The following data will serve as a basis. It has been found that a man excavates a cubic yard per hour for a day of 8 hours in ordinary soil: in stiff clay he would only do half of it, and in dry light soil he could dig and load on barrows nearly three times as much. The very worst worker should never do less than four yards a day, throwing the earth 12 feet horizontally, or 6 feet vertically. A man can wheel 20 cubic yards, or 500 wheel-barrowfuls per day to a distance of 30 yards on level ground, or 20 yards on a ramp. A horse can do the work of seven men.

Let us calculate for example, the time necessary for throwing up a work having a command of 8 feet, and a parapet 12 feet thick. Constructing a profile (123) we find that the area measures 135 square feet, so that with a foisonnement of $\frac{1}{9}$ the area of the deblai will measure 120 square feet. Adopting the first method for such a profile, as a squad occupies 15 feet, the solid content of the excavation will be $120 \times 15 = 1800$ cubic feet, or 66 cubic yards. At the rate of a yard per hour, this will require above 8 days' work.

The following is extracted from the course of fortification taught in the French Military Schools:—

"A work of 8 feet command, with parapet 9 feet thick, requires 8 days.

„	7 feet	„	7 feet	„	6 „
„	6½ feet	„	6 feet	„	4 „
„	6 feet	„	4 feet	„	2 „

"To obtain approximately the time required for a work of greater command, multiply the thickness of the parapet by the command expressed in yards; the product gives the number of days. A work ten feet high, with a parapet twelve feet thick, will, then, require about $3{\cdot}3 \times 4 = 13{\cdot}2$, between thirteen or fourteen days. In urgent cases this time may be reduced one half, by excavating on both sides."

FIG. 307.

For further details see 154.

If a work is to be thrown up in the proximity of the enemy when an attack may be made before it is completed, the parapet is no longer erected at once. It is at first made four or five feet thick, and in that state it is fit to resist musketry:

it is afterwards widened, then raised to its proper height, the banquette and its slope being formed from earth taken from the terreplein. The work may thus be constantly kept in a defensive condition whilst being erected; but the ditch being rendered too weak, a glacis becomes necessary to widen or deepen it.

When the remblai has been raised to the level of the banquette, working parties are told off to construct the revetments, which as we have said (51) are necessary to support the interior slope.

SECTION II.—Revetments.

(142). *Fascines* are a sort of faggot made of brushwood, firmly bound by several gads. Small fascines (fig. 308) are 6 feet long and 7 inches in diameter.

Fig. 308.

With stronger stuff, large fascines, 18 feet long and 6 inches in diameter, are also made. They are secured to each other by pickets, and to the parapet by a picket in the middle. The joints must be broken, and at the angles the extremities should be alternately flush.

Fig. 309.

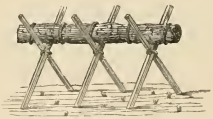


Fig. 310.

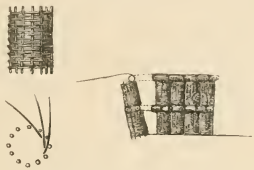
They are made as follows: Three or six tressels, according to the size of the fascine, are placed exactly in a line: these tressels are formed of strong pickets 3 or 4 inches in diameter, and 5 feet long, buried about 1½ feet in the ground, and bound strongly in the middle with twigs or rope, so as to resemble the letter X. Upon them the brushwood is laid, and when a sufficient quantity is obtained, it is compressed to the required diameter by a *choker* (fig. 310), which

is composed of two strong levers about 4 feet long, having a rope or a chain 3 feet long fastened to each end. Whilst two men draw towards themselves the extremities of the lever, a third bends the fascine tightly with *gads:* a mark made on the chain enables him to see when the diameter is right. Five gads are sufficient for a small fascine, but a large one requires about fourteen of them.

Five men can make a large fascine in one hour, and three men a small one in twenty minutes.

(143). *Gabions* are cylindrical baskets open at both ends, 2 feet in diameter, and 3 feet high. They are placed close to each other in revetments, and can stand at a slope of $\frac{1}{4}$. If used for a battery, the first row of gabions is surmounted by two rows of fascines; if for an interior slope, the gabions rest on a row of fascines half buried in the banquette, and a second row placed above the whole completes the revetment.

Fig. 311.



To make them, a directing circle, with an interior diameter of 1 foot 10 inches, is laid on a level spot, and from seven to nine pickets 3 feet 6 inches long, are fixed upright in the ground at equal distances on the circumference. The circle is thus raised and fastened to the middle of the pickets, and the basket work or *randing* * or *web*, is made above it, by taking three rods and twisting them alternately in and out round the pickets. When the rods are expended, others are taken and the work continues, care being taken to strike down the web now and then to make it stronger, and to fix it to the pickets by gads when it is finished. The gabion is then turned, and the other half finished in the same manner. The ends of the pickets are cut off about $1\frac{1}{2}$ inches from the randing and pointed.

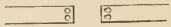
Two men can make a gabion in three quarters of an hour.

* When the web is made with more than two rods at a time, the process is called *waling;* with two rods, *pairing;* with flat bands of three or four rods, as in basket-work, *slueing;* with one rod, *randing.* This last requires an odd number of stakes.

Among the several gabions which have lately been proposed, the most serviceable, and at the same time the cheapest, is that of Sergeant-Major John Jones (fig. 312). The pickets, instead of being round, are 1½ inches by ¾ inch thick. Twelve are required for each gabion. The web is replaced by bands of thin sheet iron, 3½ inches wide, and of a length equal to the circumference of the gabion. The ends are fastened together by two buttons at one end (fig. 313),

Fig. 312.

Fig. 313.



fitting into two slots at the other. Two men can make a gabion in five minutes. A band is put together, placed on the ground, and the pickets driven around it alternately inside and outside: the other bands are afterwards placed so that each is outside the pickets, of which the former was inside, and they are pressed down close to each other. This gabion weighs only 26 pounds; it is easily unmade, repaired, and carried, and very rigid: it is calculated to last five times longer than the common wooden gabion.

(144). *Sods* are chiefly employed in the field on account of the ease with which they are procured. They are cut from meadows previously mown and watered, but are only laid when dry, or nearly so. Good sods are 16 inches long, 8 inches wide, and 4 inches thick. Sometimes two sizes are employed: headers, 18 inches long, 12 inches wide, 4 inches thick; stretchers, 12 inches long and wide, and 4 inches thick. They are built up like bricks, the grass downwards, the largest surface at right angle to the slope, and are fastened by pegs to one another. One man can lay 19 square yards of sods in eight hours, when the sods are brought to him ready cut. They stand at ¾.

Fig. 314.

(145). *Sandbags*, made of strong canvas, are a poor revetment, but are employed when no other can be had. The bags are disposed as the sods, alternating headers and stretchers, and breaking the joints. They measure 2 feet 1 inches by 1 foot 4 inches when empty, and 2 feet 3 inches by 9 inches when full, and contain when full a bushel of earth. Sixteen of them build 10 square feet of revetment, and they are disposed with their ends and sides alternately in front, the joints being broken as in brickwork.

Fig. 315.

Fig. 316.

By placing these sandbags on the top of the parapet, a loophole is made which affords cover to the men when firing. The great precision of rifle fire will render their protection still more necessary.

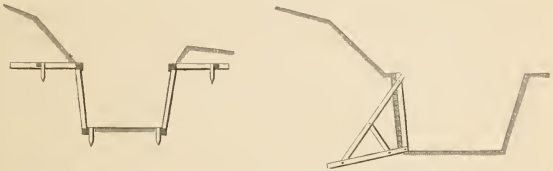
(146.) *Hurdles* are formed by driving pickets 6 or 9 inches apart into the

Fig. 317.

slope in the direction of the slope, and by interweaving twigs or rods with the pickets.

(147). *Planks*, when they are to be had, form a good revetment; casks, trunks of trees, &c., are all also employed.

Fig. 318.



It is not usual to give revetment to the scarps, except in works intended to stand for a long time; and where water is employed, timber revetments are the best.

In a paper published in the "Aide Memoire," Colonel Hamilton Smith, observing that trees in general are but little shattered by cannon shot, recommends the adoption of vegetating ramparts. With five rows of trees planted, as in the

Fig. 319.

diagram (fig. 319), and kept clear of branches a few feet off the ground, the defenders will have ample material to strengthen their position.

These trees prevent the enemy from seeing what is going on inside the ramparts: at the moment of need, the trees of the ditch and berm may be cut down, and be employed with those of the rampart to construct high stockades, palisades, fraises, &c.

The pine, larch and fir, he will plant 3 feet apart. He also recommends to plant on the glacis a hedge of holly or common furze. In the colonies, these hedges would be of cactus undecimalis, and the plantations of cocoa and palm trees.

(148). The best revetment for field purposes is that formed of gabions, because it requires less trouble than any other, and requires less wood than fascines. Gabions stand in the revetments without fastening, can be placed by any workman, and last longer than fascines, which require skilful men, and besides do not resist so well in embrasure cheeks. Sods require much labour, and a sod revetment takes three times as long to build as a work of brick of equal dimensions. Sandbags are expeditious, but do not last, and as they rot within two months, they require tarring.

For the construction of batteries (96, 205) fascines are, however, preferable as presenting no joints to be loosened by the explosion of ordnance. Gabions are suitable for the cheeks of the embrasures, and for traverses; sandbags are excellent for powder magazines, traverses, and mortar batteries. In the batteries constructed before a fortress, especially in those thrown up towards the latter part of the siege, these three revetments are frequently employed simultaneously. (*see also* 201).

SECTION III.—Communications.

(149). *Communications.*—When an open work is completed, its gorge is generally closed with palisades or *chevaux-de-frise*, with a barrier for the ingress and egress of the garrison.

Stockades may also be employed, and planted on the outline of a bastioned front, or some other tracing that will give flanking fire.

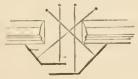
Fig. 320.

(150). In enclosed works, an opening, 2 yards wide, or 6 feet 6 inches when destined for the passage of artillery, is always left on the side the least exposed; and in order that the enemy may not see the defenders in reverse, a mass, called a *traverse*, is erected inside, either with or without a banquette.

Fig. 321.

These traverses can be organized defensively by forming them of two parts respectively crossing their fire. In the defence of a village, the above

Fig. 322.



disposition has been found most advantageous. In 1757, when the Austrians found it impossible to batter down the walls of Gabel with their 12-pounders, they forced open one of its gates, and some companies rushed into the town; but meeting with traverses in their front and on both flanks, they were obliged to retire with considerable loss.

We sometimes hear of cavalry storming field-works. This is a mistake. Cavalry cannot storm a work, but may turn it, and when the gorge is not defended by palisades, barriers, &c., it can rush on the garrison, and become master of the intrenchment. At the battle of Borodino (1812), the French cavalry thus took the Russian redoubts. A similar occurrence had taken place in 1760, near Weissen-Hirsch, when the Austrians were marching to the relief of Dresden.

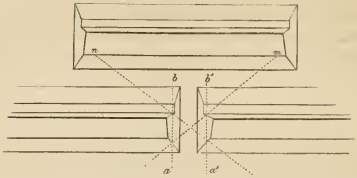
In forts, the opening is left in the middle of the curtain, and is covered

Fig. 323.

by a small redan, or ravelin. It is either a mere palisade, itself provided with a barrier, or a regular redan, with its ditch communicating with that of the fort. In the latter case, a covered way is generally formed, and openings are made into the face of the ravelin, and also in the covered way (367).

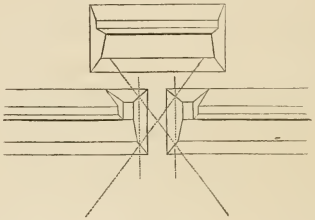
The traverse destined to prevent the enemy from directing a reverse fire should be sufficiently long to intercept the whole. As a man fires at about $4\frac{1}{2}$ feet above the ground, it is clear that we may imagine a plane of fire parallel to the ground, and $4\frac{1}{2}$ feet above it: this plane will intersect the profiles on both sides of the opening on lines $a\,b$, $a'\,b'$ (fig. 324) parallel to their bases, and at 4 feet 6 inches

Fig. 324.



from them. The extreme shots which the enemy can send into the work are those directed on $a'b$, ab'; the traverse should therefore extend 3 or 4 feet beyond the points m and n, where it is met by these two directions. In general the traverse will be long, and in order to diminish the labour of its construction, it is advantageous to construct a small bonnette 3 or 4 feet thick on each side of the entrance.

Fig. 325.



Many sorts of barriers are constructed: the following are at the same time strong and simple, and will answer for a passage through a palisading.

Fig. 326.

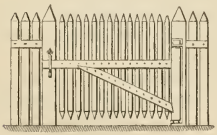
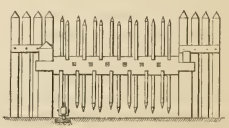


Fig. 327.



Chevaux-de-frise may also be employed.

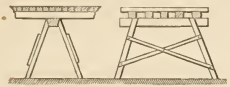
All these barriers should open internally.

(151). When the work is defiladed by means of traverses, it is necessary to cut passages through them to facilitate the communication. These passages may be constructed as mining galleries, with frames or cases, and should be 6 feet 6 inches wide, to allow of the passage of artillery. These traverses serve also to shelter powder magazines.

Advantage must always be taken of these traverses for the defence. The traverses for the defilade of Fort Little Gibraltar, at Toulon, were combined to contribute actively towards the defence, and the losses of the storming-party testify to their value.

(152). To cross over the ditches of enclosed works, moveable bridges are formed; for narrow ditches, three or four sleepers laid across, and covered with planks, are sufficient. For a greater width, one, two, or three, or more trestles, support the sleepers. (173.)

Fig. 328.



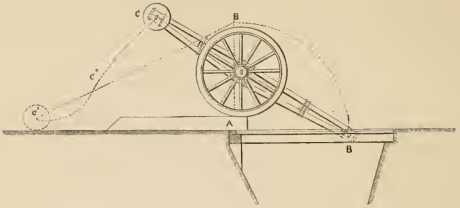
When the width is small, two little wheels adapted to the bridge permit it to be moved along the sleepers.

Fig. 329.

A kind of drawbridge can easily be constructed by means of two pairs of wheels.

Each pair carries on its axle a long lever strengthened in its middle, or a pair of levers of the form C B (fig. 330.)

Fig. 330.



The platform of the bridge is fixed to the extremity B, whilst the other extremity carries a counterpoise made of shells or a mass of metal. The wheels being moved, the counterpoise describes a curve C c'' c', and the bridge is drawn. It is maintained in a vertical position A B', by means of bolts that can be fitted into a pair of strong posts.

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CHAPTER XX.

MILITARY POSTS.

(153). As we have said, it is not always possible in the field to throw up works with accuracy; the chief of a detachment, upon receiving news of the arrival of the enemy, cannot waste time in calculations, but he sets his men to work at once, and makes them excavate a trench that will give a cover, which, time permitting, is afterwards converted into a regular breastwork. Tools may be wanting; in which case, recourse is had to such accidents as the ground may present. It would require volumes to enter into the never-ending details of the peculiar circumstances in which the vicissitudes of war may place an officer. If he is well acquainted with the principles of fortification, it matters but little if he cannot recollect all the figures and dimensions given above; his sagacity will suggest what is best to be done. It is needless to tell him that if he has to defend a village against an enemy having artillery, he must remove the thatch from the roofs, barricade the streets, &c. &c.

A mere wall will become a good cover for him.

Fig. 331.

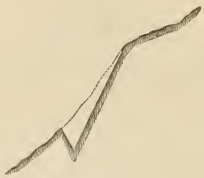
A hedge, with little trouble, will be transformed into a breastwork.

Fig. 332.

The banks of a river, when ever so little inclined, will soon become a good position.

The slope of a hill, by merely cutting down the inequalities it presents (an operation called *scarping*), will render his position difficult of access.

Fig. 333.



The more we investigate this subject, the more convinced we become that military history is the best complement of all military sciences. There, indeed, we see that *much* can be done with small means.

In India, sun-dried bricks, mud, and even tiers of camel saddles, have served to construct intrenchments. At Paris, paving-stones have answered the same purpose. At the attack of Edinburgh (1688), at Fort San Christoval (1810), at Bhurtpoor (1825), in America, &c., cotton bales and woolpacks have proved of great advantage. At Lisbon (1810), scarping was employed on a large scale. At San Sebastian (1812), a redoubt was erected with casks to support the trenches of attack on the isthmus. At Badajoz, sword-blades, transformed into chevaux-de-frise, became an insurmountable obstacle, &c. &c.

The French term passagère (temporary), applies admirably to this kind of fortification constructed at a minute's notice, with the materials found on the spot, either on the eve of a battle or for the defence of outposts. It is the application of the principles, which we have exhibited, to the various obstacles which nature offers; the strengthening of these obstacles, the combining of their properties, together with the seeking in the ground for additional defensive advantages, constitute in fact the practical part of the science. Officers of the line are not likely to be entrusted with the tracing of those works which a general constructs to secure the front or the flanks of his army previous to battle; this care generally devolves on some officers of the engineers; but any officer may be called upon to obtain cover for his men, to intrench a detached post, to defend a house, &c.

Colonel Jebb, R. E., in his work on "the Defence of Outposts," has so admirably treated this subject that we shall, with his permission, borrow from him a few pages, first, on the time necessary to obtain immediate cover, secondly, on the defence of hedges, roads, walls, &c., from 154 to 157.

(154). Before entering into details, it may be right to mention as a general rule, that in almost all cases where trenches are required, it is essential that the means of getting out of them with facility, both to the front and rear, should be preserved, by leaving slopes or steps for that purpose. Thus on some occasions it is desirable they should offer no impediment to a forward or retrograde movement, but that troops should be able to march straight over them when necessary. In the trenches, however, which will now be brought more immediately under consideration, and which are designed not only to provide cover, but to be vigorously defended when attacked, the chief object in making a step in the rear would be, that the defenders instead of waiting for the assailants in the bottom of the trench, might step out after giving their last fire, and thus interpose a fresh obstacle between them and their enemy, besides placing themselves in a better attitude for resistance.

Fig. 334 represents the section of a small trench, and the parapet or breast-

Fig. 334.

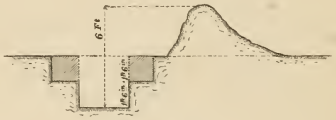
work that has been formed by throwing the earth in front of it. The trench is 2½ feet deep, and the same width, having a rough step 1 foot broad in the rear. The earth thrown out will make a parapet of a height nearly equal to the depth of the trench, without taking any precaution in building it up at a proper slope different from that at which it will stand of itself; we will assume that it is 2 feet high, which will make a total of 4½ feet from the bottom of the trench. A man, therefore, though he can reach to fire over the top of the parapet, has to stoop to be wholly concealed or covered by it, and it therefore affords as little protection as can be of much service.

From the solid content of the excavation may be determined the probable time it will take to execute it; this is found by multiplying the depth and breadth of the trench together, for the superficial measure or area of the section, and that product by the length each man has to do. Here 2½ multiplied by 2½ feet is equal to 6¼ square feet; and this product, multiplied by 6 feet, which we have assumed to be the portion allotted to each workman, gives 37½ cubic feet. The step is 1 foot broad and 1 foot deep, and being 6 feet as before in length, there will be 6 solid feet more to add, making altogether 43½ cubic feet for the solid content of the mass of earth that has been removed.

Now, if a man is only supposed to dig out 27 cubic feet in an hour, it will take him rather more than an hour and a half to remove 43½ cubic feet on level ground.

Fig. 335 affords more cover, for the top of the parapet is 6 feet from the bottom

Fig. 335.



of the trench. The best way of executing such a profile would be to sink a trench 3 feet deep and 3 feet wide, and to throw the earth about 2 feet in front of it; so that in the progress of the work, when the trench was found to be too deep to stand in, and fire with convenience over the top of the parapet, a little step might be cut out of the solid left in front, for a banquette, as shown shaded in the section; and another step of the same description in the rear would complete it as far as it went. The steps might be 18 inches wide, and the same depth.

The area of this section is nearly 14 feet, the trench itself being 9 feet, and the two steps 4½ superficial measure, which, multiplied by 6 feet, the length of the portion allotted to each workman as before, gives 84 cubic feet, or about 3 cubic yards, for the solid content of the excavation; and, therefore, under the presumed data, it would be completed in three hours; still, however, it will be observed, that it offers no impediment in itself to an enemy, and men could only be drawn up in single file for its defence, from a want of room for more.

A trench of the dimensions shown in fig. 336 might be completed in five hours on the presumed data; and being roomy enough to dispose men in double files for its defence, and high enough to screen and cover them, it may be considered

Fig. 336.

as large as is necessary for merely fulfilling these conditions; for if more time could be devoted to strengthening a post, or if other circumstances were favourable,

it would become a consideration whether some profile of a different form could not be substituted with advantage, for such a one as only affords cover, without opposing any obstacle to the advance of a hostile force.

Fig. 337 is a form of breastwork that might be adopted for obtaining cover in

Fig. 337.

rocky or marshy situations, where a ditch or trench could not be made deeper than 1 or 2 feet; and if there were plenty of men, they might be set to work in two lines, and get it completed in half the time it would otherwise take, either by sinking on each side of the proposed situation, or by arranging the men in two lines behind it, as shown in the figure, where the situation for the second line of workmen is shown at (*a*).

To work on both sides of the breastwork, which is the quickest way, would render it necessary to calculate what breadth of ground the breastwork, with its slopes to the front and rear, would stand upon, and what breadth the banquette and berm ought to be. These particulars being determined, two parallel lines would be roughly traced on the ground, with pickets, at the required distance. The workmen would be drawn up, facing each other on these lines, and would work backwards, throwing the earth into the space between them, which some spare men would form into the breastwork. Here, though sinking only 2 feet, the breastwork must be raised 4½ feet to obtain cover. Suppose the slope on the inside is made steep by building it up with sods, or other materials, so that it only occupies 18 inches of level ground, the outside slope, being left to find its own level, will require a base equal to its height, or 4 feet 6 inches; and if we add 2 feet for the thickness of the breastwork at the top, it will cover 8 feet of ground. Then if the banquette be made 2 feet broad, and the berm 1 foot, the distance between the two lines of workmen will be altogether 11 feet.

Under the second supposition, if the two lines of workmen were drawn up one behind the other, and both working to the same front, the distance between them might be from 4 to 7 feet, according to the depth.

The level of the ground in this instance forms the banquette or step to fire from. There will be about 5 cubic yards in 6 running feet of breastwork, and as

there is supposed to be a double number of men at work, it ought to be finished in two or three hours.*

This mode of executing work may also be adopted with advantage in other cases when time is an object, and there are plenty of hands, or when it is of importance to strengthen and give height to breastworks in particular situations. But as far as this profile is concerned, it is to be observed, that it would afford cover to an enemy when he reached it, without opposing any impediment to his advance, which it is always very desirable to avoid.

Should the ground be rocky or very hard, as in a road or street, cover may perhaps be more expeditiously obtained by raising a breastwork from rubbish or materials brought to the spot in baskets, sandbags or barrows, than in attempting to sink at all. Different expedients are shown in figs. 338 and 339.

Fig. 338.

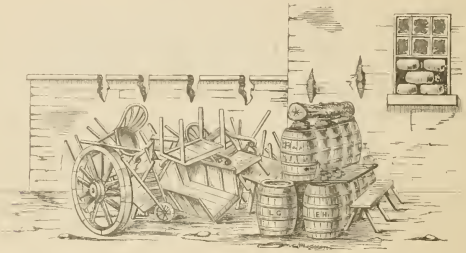
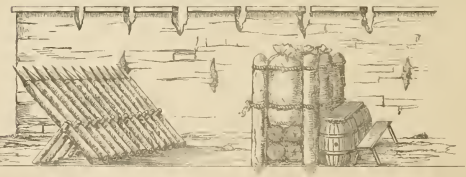


Fig. 339.

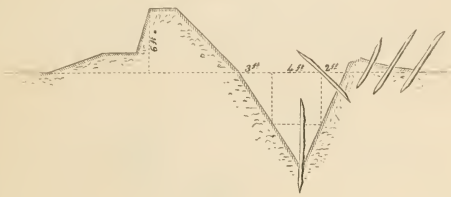


* When necessarily, the depth of a trench or ditch is very limited, the probable time it will take to form a breastwork out of them is more readily determined by estimating the content of the *mass* to be raised, than that of the *excavation*, as in the preceding cases, because the breadth of the latter will probably be irregular.

Having thus far detailed the most expeditious mode of providing cover for men, it may now be worth while to consider whether, in securing that advantage to the defenders you cannot at the same time gain another by opposing an *obstacle* to an enemy, by excavating a ditch in *front* of the breastwork, instead of making a trench in rear of it. A ditch to stop an enemy at all should be too wide to be jumped over either "flying" or "in and out," and it should therefore be at least 8 or 9 feet broad and 6 or 8 feet deep. In more permanent works it should of course be considerably larger.

Fig. 340 shows the general dimensions which such a profile might have. The

Fig. 340.



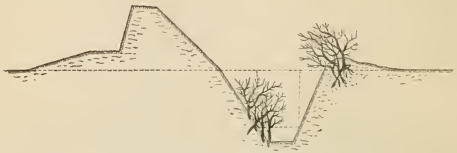
ditch, it will be observed, is of a triangular form, and its area which must be found in order to calculate the quantity of earth to be moved, will be obtained by multiplying its breadth by *one-half* its depth, that is, 9 feet by 4 feet, which gives 36 superficial feet; and this again multiplied by the length of the portion each man has to excavate, we will say only 4 feet, since the breadth is considerable, will be 36×4; which, considering the increase of labour arising from a greater depth than usual, would not probably be completed in less than six hours by the same sort of workmen as we have supposed engaged in other works. Some spare men, say one-half the number employed in the ditch, would also be required for ramming the earth, and forming the breastwork. Thus, on 100 feet in length of the ditch, there would be twenty-five men working, and twelve additional, making in all 37; whilst in the common trench work, which has hitherto been under consideration, only about seventeen workmen have been shown to be necessary for every 100 feet.

A profile, such as the one under discussion, therefore requires not only longer time to execute, but double the number of men; and it would not seem advisable to undertake it, unless there was a reasonable probability of its being completed before an attack could be made; for if an enemy came upon it when in an unfinished state, it would be almost useless, and the labour, which if otherwise applied would

have secured at least good cover, would thus be thrown away. Still, however, the advantages it offers should not be lost sight of in situations where a determined stand is to be made, and on very accessible points, or where it is desirable to shut up roads, streets, &c., even if the rest of an intrenchment were differently arranged. As far as the means of resistance is concerned, it is obviously of more advantage to have a ditch in front of a breastwork than a trench in rear of one; and the only point to be determined is whether there are time and means for executing it; and it is on these points that an officer will have to exercise his discrimination, when he has carefully considered the various circumstances which will have influence upon it.

Such a profile may further be much strengthened by planting a row of palisades in the ditch, or even by driving stakes into it, and sharpening them, or making what may be called a perpendicular abattis, by planting brushwood upright in the bottom, with the ends sharpened, as shown in figs. 341 and 342.

Fig. 341.



An expeditious way also of adding to the difficulties of an assault is shown in

Fig. 342.

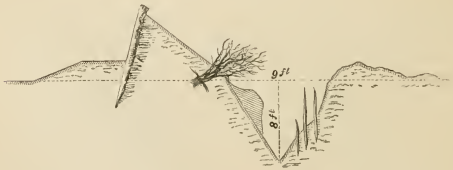


fig. 342, where common hurdles or gates, rails or brushwood, laid on the ground soon after commencing the work, with their extremities buried under the parapet, may be made use of; the earth underneath them, shaded dark in the figure, should be cut away when the ditch has been sunk to its full depth.

Short posts laid horizontally every 8 or 10 feet in the same situation, with long

rails or a chain afterwards nailed to them, would be a ready expedient: the ends should project about 2 feet over the ditch, and stand at least 6 feet above the bottom of it.

It is to be observed, that in all the foregoing cases ONLY A MINIMUM OF COVER AND MEANS OF RESISTANCE has been sought for, in a MINIMUM OF TIME. It has been shown WHAT CAN BE EFFECTED IN A FEW HOURS, "*faute de mieux.*" It may happen, however, that time is given to improve upon the profiles described, as would be the case if an advanced post were held for some days in succession, and each officer in command had done what he could towards it. These improvements would consist in strengthening the breastworks, making the ditches deeper and wider, and in planting more redoutable obstructions; and such opportunity must never be thrown away, as the means of defence, and the security afforded, will be augmented in proportion.

It may be remarked that such breastworks as offer little or no impediment to the enemy, if well laid out, permit the defenders to charge over them in line if they wish it, and still possess one of the principal attributes of any work, which is that of affording screen from *previous observation.* But a forward movement from those that do offer an obstruction, must be through an opening, and therefore on a narrow front.

Now the space between a breastwork and an obstruction placed in front of it is ground belonging to the defenders; and this, if circumstances permit, should be disputed; and as an enemy would probably be in some confusion in forcing his way through such obstruction, a favourable moment would doubtless occur for making a sudden charge, which, if supported by a good flank fire, ought to be successful. These advantages should never be lost sight of, in arranging the general plan of defensive works, and in determining the profiles they shall have.

The salient angles of the intrenched line are the points most open to attack, and it will be observed that the profile of the lines, terminating in those salients, has a ditch in front, which presents more or less of an obstacle; whilst the profile of the line adjoining the battery in the centre, is only that of a trench for providing cover, because it is not in a situation open to attack.

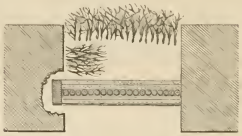
When an opening or passage is required through a breastwork or stockade, it must be arranged so as to be easily closed and defended. These objects may be in some measure secured by disposing the lines in such forms as are represented in figs. 343 and 344, and providing rough strong gates, chevaux de frize, or some-

FIG. 343.

FIG. 344.

thing of the sort, for quickly shutting them up. When houses are concerned, as in a street, the barricade may extend quite across, and a communication may be made round the end of it by breaking through walls, as shown in fig. 345.

Fig. 345.



(155.) *Hedges, roads, &c.* — In the foregoing explanation of the details of breastworks, an attempt has been made to show the least possible time in which decent cover could be obtained when working on a level plain unaided by any advantages of ground and situation; and it may be confessed that it is rather a damper to one's ardour to find, that five or six hours of hard work may be calculated upon, before anything like *comfort* can be obtained under such circumstances, and that the men who should be kept fresh for resisting an attack, are likely to be worn out by their exertions in preparing for it.

This, happily, however, is by far the worst side of the picture, for with a moderate share of luck, some little slope or broken ground will offer itself; and some hedge or ditch, bank, wall, road or wood, will be found, either placed exactly as if it were there on purpose to be defended, or a plan can readily be formed for turning it to some account. The eye is put into a man's head to be made use of, and it only requires a little previous exercise of that organ, to see all these natural intrenchments and local advantages in almost every possible circumstance of ground and situation.

An endeavour will be made to explain by sketches the simple means which are most in use, and which appear adapted for improving, and deriving advantage from such local objects as are most commonly met with, in the hope of showing that by the *judicious application of a very little labour*, a serious, and in some cases an almost insurmountable obstruction may be formed.

Fig. 346, represents a hedge on the top of a steep bank which has been cut down within two feet of the ground. The branches have been carried to the front as an obstacle, and two small steps have been made on the slope, the one to load on, the other to fire from.

Fig. 346.

Fig. 347, is supposed to be the same situation, but defended in an opposite

Fig. 347.

direction. The hedge might be felled as an obstacle, leaving the stumps 2 feet high to screen the men, or it might be cut thin and left standing, if it were considered better. The slope in front is made steeper, and a little hollow is made to fire from, kneeling.

Fig. 348, a ditch on the side of the enemy, is supposed to have been deepened,

Fig. 348.

and the earth and sods formed into a breastwork on the reverse of the hedge; where a small trench has also been made, to obtain additional cover.

Fig. 349, is the same, fronting the other way. The hedge is felled as an

Fig. 349.

obstruction, or cut thin, so as to give no cover to the enemy, and is left standing. The ditch is deepened to 6 feet, and a small breastwork is made of the earth thrown out of it, and out of a trench in the rear.

Fig. 350, represents a double post and rail. Brushwood is interlaced in the

Fig. 350.

front rail as an obstacle; and a breastwork is made leaning against the other to afford cover.

Fig. 351, represents a bank with double ditch. One ditch has been deepened, and the other partly filled up.

Fig. 351.

Fig. 352, represents the edge of a quarry or steep bank, a very defensible situation.

Fig. 352

Fig. 353, a wet ditch, or brook. The breastwork is made from a trench in the rear.

Fig. 353.

Fig. 354, a road. Both fences felled as obstructions, and a breastwork placed for defending them.

Fig. 354.

Fig. 355, a hollow road, arranged in a similar manner.

Fig. 355.

Figs. 356 and 357, are profiles on a bare steep rock, to show the way of

Fig. 356.

Fig. 357.

obtaining cover in such situations; but where means are so very obvious, it perhaps might not be considered *complimentary* to multiply examples.

It may be remarked, that as obstructions placed under a close fire in front of temporary works are essential to their being properly defended, it will be a consideration whether a hedge would be more conveniently converted into such an obstruction as in Fig. 349, or made to form part of a breastwork, as in Fig. 354.

A strong growing hedge is of great value for either purpose: hunting men will bear witness that there is many a *big* fence, across the verdant fields of Leicestershire, that is not to be got over by man or beast, except here and there at some "*Soft place*," in single file. And who has ever been out shooting, and has not now and then fallen in with a puzzler? A small weak fence, for instance, a thing that looked like nothing, leaning towards him from the top of a bank, but which took him something like five minutes to get over; which five minutes, if spent within fifteen yards of a posted enemy, would have afforded time for about twelve rounds being quietly fired into his body by each man who could see him.

Before setting his men to work, it is necessary for an officer to have a notion of the time it will take to execute his projected defences; for this purpose he might

pace the whole length of his proposed line, and then by forming an idea how long it would take one man to finish a certain portion of it, say 4 or 5 yards in length in the case of deepening a ditch, scarping a bank, or felling a fence, he would see whether the number of men at his disposal could complete the whole in a given time, and would curtail or enlarge his plan accordingly, and distribute his men at intervals of 4, 5, 7 or 8 yards, as the case might be; for it is impossible to offer any defined rules which shall apply where circumstances are ever varying. This however, must be borne in mind, that there is *more wisdom in doing a little well, than in attempting too much.*

A stick may be cut for measuring out the portions, and stakes may be driven in for explaining the slopes and the general form of the profile that is required.

(156) *Walls.*—Walls are readily made available for purposes of defence by loop-hooling them, the mode of doing it varying with their height and situation.

It is a general rule that loop-holes must be so placed that if an enemy succeeds in rushing up, he shall not be able to reach close enough to make use of them; for it is clear that if he stands on the same level as the defenders, the loop-hole would be equally convenient for both parties.

To obviate this inconvenience, loop-holes should be placed 8 or 9 feet above the ground on the outside; but on the inside, the banquette, or step from which the defenders are to fire, should not be more than about 4 feet 6 inches below them, which may be assumed as a convenient height for the purpose, as already explained in treating of breastworks. A portion of the wall also, not less than 18 inches high, should be left *above* the loop-holes, where there is opportunity, for the purpose of securing the men's heads when giving their fire.

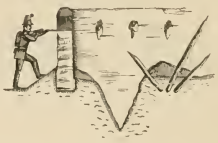
These points are attainable in several ways; and circumstances must decide which is the most convenient; for example, if a wall were 10 feet high, the loop-holes might be pierced within 18 inches of the top, and a temporary stage might be made of casks, waggons, ladders, &c., or an earthen banquette might be thrown up inside to fire from.

Fig. 358.

And in cases where a very determined resistance is to be made, a second

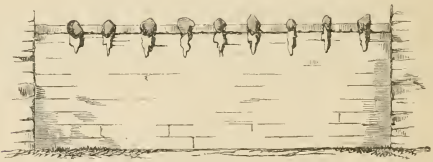
row of loop-holes might be arranged, as shown in that figure. On the other hand, if a wall were only 6 feet high, the loop-holes might be pierced 4 feet 6 inches above the level on the inside, and a ditch cut on the same side to obtain the requisite height, which arrangement would save the trouble of making any banquette.

Fig. 359.



The quickest way of making a loop-hole is to break a wall down from the top to a depth of 2 feet, in the form of a narrow fissure, at intervals of 3 feet or more apart, and as this can be done with common pickaxes, if there are no better tools at hand, it will generally be found a more convenient mode than cutting them through the wall, when time is an object. Such loop-holes will appear as shown in fig. 360.

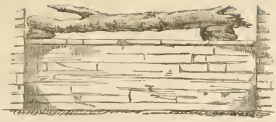
Fig. 360.



It will be seen that they are not quite so safe to fire from as others, but this inconvenience may be partially remedied by filling the upper part with a stone, a log of wood, a sand-bag, &c.

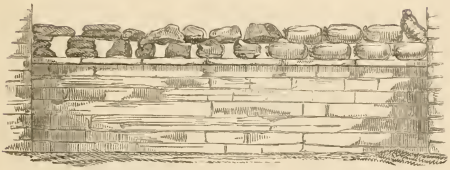
If a wall should be very low, or there were not time to make loop-holes, a piece of timber, or the trunk of a tree, supported by a couple of stones, on the top of it, would be a ready expedient, and men could fire from the opening under it.

Fig. 361.



If at hand, sand bags, having loop-holes between them, might be placed on the

Fig. 362.



wall: or large stones, or sods, might be placed there in default of sand bags. A man of resource would seldom find any difficulty in adapting something to his purpose.

The temporary loop-holes that are made in walls or buildings are not of course confined to any regular form; they are merely holes to fire through, made in the required direction, so that the ground may be seen as far as from within a few yards of the foot of the wall or building into which they are pierced, to the extreme range of a firelock, affording also the opportunity of firing a little to the right and left.

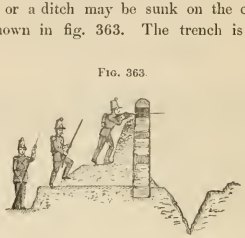
To secure these points, the absolute dimensions will vary with the thickness and height of the wall; the width of the hole outside, however, need not exceed about 3 inches; but the width inside should, if possible, be equal to the thickness of the wall (374).

The best tools for breaking loop-holes through brickwork or masonry with, are short iron bars, steeled at the head, called hand-borers. They are held in the proper position by one man, and struck with a sledge-hammer by another. But if men are employed who have not been accustomed to the use of such tools, they would perhaps get on better if each man had a crow-bar, which anybody can handle. A beginning might be made on the face of a wall with a pickaxe, which would very much facilitate the work. The time it will take to break

through a wall will be best determined by a trial on the spot; for materials are so various, that it might lead to erroneous conclusions, were any attempt made to state a general average. Much also would depend on the tools and workmen, which adds to the difficulty of offering any precise data.

A wall exposed to the fire of artillery will not afford very good cover, in consequence of the splinters that will fly from the materials whenever it is struck; but if there is time, this inconvenience may in some measure be obviated, by sinking a trench a few yards in the rear, and throwing the earth up against the *inside* of the wall: or a ditch may be sunk on the outside, and the earth be thrown over, as shown in fig. 363. The trench is best, as it will give

Fig. 363.



additional protection to the men; but the ditch may be required as an obstacle, or to give height to the loop-holes, and therefore, as usual, circumstances must decide what is best to be done. It is not contemplated that there would be opportunity for giving this embankment sufficient thickness to make it shot-proof, but most of the splinters would bury themselves even if it were only 3 or 4 feet thick.

Buildings.—In his treatise on "Reconnaissances Militaires," * Major Chatelain points out most minutely the various points to which an officer must direct his attention when selecting a building for the purpose of defence; and we shall borrow from him. As a matter of course he assumes that a careful reconnoisance will be made.

(157) Houses.—In establishing a post in a house, the *site*, *outline*, *and size* of the intrenchment are fixed. The difficulty consists in making the best of the building and its approaches.

A house fulfils the conditions necessary for a good defence—

(1) When it is situated at the place that suits best the purpose of the post;

(2) When it commands all the surrounding ground;

* "Traité des Reconnaissances Militaires, 2 vol, Paris, 1847.

(3) When it furnishes the materials necessary for its defence;

(4) When being of easy access, it nevertheless affords a safe retreat;

(5) When its size is in proportion to the number of men destined for its occupation;

(6) When the walls are good;

(7) When its various parts mutually flank each other;

(8) When it can be put into a state of defence with the means and time at disposal.

No house fulfils all the conditions which we have just enumerated, but we remedy this by particular dispositions and additional works. To make a good defence with a house and its dependencies, we should attentively study each part and its relation to the whole; and presuming, at least, if not knowing precisely, the means of attack, we should calculate the means of defence on the strength of the detachment combined with the resources to be derived from the locality. All this implies a minute and careful reconnaissance.

Almost every house, even in ordinary conditions, differs from any other, either in the *site* upon which it is built, in its *dimensions*, in its *distribution*, or its *dependencies*.

The site.—The post which always requires the most attention is that which is situated near the most important passage, or on a communication which it is desirable to close against the enemy. Whatever may be the configuration of the ground, the house ought to be isolated from everything that surrounds it, and should not be commanded by a height or another house; but it ought always to be near the passage intended to be guarded. We should select, within the limits which we shall presently give, those houses that best suit the locality.

Dimensions.—If the house belongs either to a simple agriculturist, workman, or keeper, it will probably be small and possess but little solidity, and will rarely be capable of a good defence; a farm with several barns and stables offers few resources, few dwelling rooms, and only occasionally a yard and a garden, which are mostly badly walled in. An inn will be larger in comparison, as it is situated on a more frequented road, and at a convenient distance from a town for post-horses. Country houses are also to be met with, of one or more stories, with yards and gardens. Industrial establishments, such as mills, ironworks, paper manufactories, &c., consist of groups of buildings, and some have several stories; water is generally found there, of which use can be made in the defence.

Distribution.—A house contains rooms or halls, the size and disposition of which are to be studied, in order to know well the manner in which each part ought to be defended; the same for doors and windows. Barns, coach-houses, and stables, occupy the ground-floor, or form distinct buildings. The yards are enclosed by buildings, or merely by walls, palisades, &c., the same as gardens

and parks. The ground-floor will be more useful if it is elevated a little above the surrounding ground. If the house is isolated and composed of a single block, the project of defence will be easy and simple; but if it forms part of a group, we must keep well in mind the disposition of these houses compared with the combinations of the defence. If the detachment is too weak to defend the group, it is necessary to demolish the contiguous houses, or at least to knock off the crest in order that they may not command it. If it were more advantageous to defend them, they must be joined to the principal building, and easy communication covered from the enemy's fire must be established between the one and the other.

The construction.—If the house is of wood or thatched, the enemy could burn and destroy it, unless the defenders build around it an earthen intrenchment, hiding from his view the most exposed walls, or may *erect blinded cover on their sides* (485). If the roof is of straw or of shingle it is indispensable to demolish it. When we have time at disposal, we also take down the roofs of tiles or slates to make use of the material, or to avoid their being splintered by the cannon.

Brick walls are the best, because a shot only makes its own hole in them whilst in walls built of rough stone, or even of cut stone, it throws over whole blocks. Stories above the second one are often injurious, because a ball reaches them easily, and the debris incommodes the defenders. Shots fired from these stories are besides too plunging. A thickness of wall from 1 to 2 feet is the most advantageous, because it offers the desirable solidity, and is easy to pierce for loopholes. Old walls offer little resistance; very old houses are not capable of a good defence.

Dependencies and approaches.—The dependencies are blocks of buildings separated from the rest, as stables, coach-houses, workshops, enclosures of yards and gardens, &c. Only those objects which can be made useful in the defence should be preserved. We should not forget that the house is the principal object, the reduit of the system of defence. Trees, to the distance of 200 yards from the position which might favour the attack of the enemy must be cut at the height of two feet from the ground; the same with hedges and thickets. Ditches and holes in which the enemy may find shelter must be filled up. The enclosure walls, outside the position to be defended, which might afford any aid to the enemy, must be demolished, and the materials must be spread about so as to prevent any undulation. Stacks of wood or hay found near the position must be burned, reserving always what is useful, carrying it quickly into the magazines of the army. In a word, we should endeavour to isolate the house, to cut down anything which facilitates the approach, to level the ground around to a distance of 200 yards, in order that the enemy may be seen from the position from head to foot, and even to render impracticable the roads in the neighbourhood except that of retreat.

Of the means to prepare for the defence.—In the first place, *for the execution of the works,* endeavour to procure the necessary tools, such as spades, shovels, pickaxes, hammers, saws, pinchers, wheelbarrows, earth or sand bags, cords, ladders, &c. A few, no doubt, will be found in the house or the environs. In many instances different materials are also wanted, such as beams, planks, boards, nails, stones, &c.; the house itself or the neighbouring houses will probably furnish them. Nevertheless, it is possible that a part, or even all of these objects, may be wanting, and, time failing, the dispositions for the defence ought none the less to be made with the means we already have. If there are inhabitants at a little distance, they can be employed in moving the earth or transporting materials.

The defence of a house comprehends the measures to be taken in the interior and exterior.

In the interior.—Doors which open outwards must be strongly barricaded within. One of them must be arranged so as to open for going out, if a moment arrives when a longer defence becomes impossible. The windows are barricaded also by means of planks or a double row of boards; in default of wood the windows must be stopped up with casks or sandbags, and the same measures are taken with regard to the openings leading to the cellars, so that the enemy cannot throw powder or other incendiary projectiles.

The principal door must be covered by a tambour of palisades or stockades in the form of a redan flanked by the interior of the building, pierced with loopholes. If the door, thus strengthened, cannot offer an efficacious resistance, an abattis, barricade or other obstacle must be established five or six paces in the rear, from behind which a few men can defend the entry to the house.

The interior doors must be partly barricaded, there being left at each sufficient passage only for one man. Large stones, trunks of trees or furniture should be ready near these doors to obstruct the passage after retreat. Loopholes must be pierced round the ground floor, either in the walls or the fastening of the doors or windows, and also near the angles of the building. The upper stories must also be loopholed, but less closely than in the ground floor, because only a few men will suffice to fire into the hollows adjoining the house. When the ceilings are lofty, two rows of loopholes are made, and the superior one is reached by means of a banquette or scaffold.

If there are balconies, they are furnished with mantelets or beams; and flanking fire is thereby obtained; and in cutting openings through the floor or flagstones above the door, we obtain machicoulis from which the foot of the wall may be seen.

If the enemy is able to attack with artillery, it is necessary to prop up the floors near those walls which are too weak to resist the shot. If great breaches are to be made in the walls, an intrenchment should be made behind, from which the

enemy could be opposed when attempting to penetrate. Loopholes might also be pierced into the partition walls, to facilitate fighting from one room to the other.

If the defenders have cannons, they should be placed on the spot exposed to the first attack, such as the angles of the house, or in the direction of the roads that lead to them. Besides, embrasures should be cut through the doors, and closed by shutters.

The staircases leading to the upper stories must be demolished, or if time is wanting, they must be blocked up with casks, great stones, or other objects, to render them impassable; they may be replaced by moveable ladders, which may be carried away by the defenders. The entrances to the rooms, coach houses, or other places which are not to be defended must be blocked up.

One of the remotest parts of the house, the one that is the least exposed to the first attempts of the enemy, must be chosen to form the reduit and magazine, or place of arms, in which is placed a portion of the provisions and ammunitions. Should there be a tower or a keep, a reduit is made of it. The dispositions of the defence of this part are made with particular care, and so connected with the rest of the building, that the retreat thereinto may be easily made, and that the enemy may not be able to approach it.

The first floor requires similar means of defence to those of the ground floor: the windows are barricaded and pierced with loopholes; the walls should only be pierced when the windows are too far apart.

If an escalade is feared, at the foot of the exposed windows, an opening in the floor must be made in the form of a ditch, which must be covered with moveable planks to approach the loopholes without accident. These openings also serve as machicoulis for the defence of the other rooms of the ground floor. In case of an urgent retreat, two windows on the first floor are reserved in which the barricades are easily taken away, so as to afford means of escape by the help of ladders.

If there is no time to take off the roof, as before said, openings must be made through it, in which skilful marksmen are put to keep off the enemy if he attempt to escalade over the top of the house.

It will be prudent to spread over the floors dung or rubbish, about a foot thick, to avoid fire, and if the floors be not strong enough for this overweight, it will be necessary to prop them up.

Tubs and casks filled with water are carried up to the first story; and also planks, stones, and utensils for boiling water, and for throwing it on the enemy if he attempt to escalade, &c.

On the outside.—Tambours are built up on each side of the house similar to the one established behind the entrance door, or they are constructed at the angles in order to flank the circumference better, if the sides of the building are

long: and the walls are pierced to communicate with the interior of these works.

Fig. 364.

A machicoulis gallery may be constructed on the first floor; when there are balconies this is very simple; when none exist, some construction of timber, as in this diagram, will be found advantageous, either above the door, or along the whole front of the house.

Outside the house a triangular ditch is dug, two yards deep; the slope resting on the walls ought to be higher than the ground, so as to leave no berm which the enemy might use for escalading or for stopping up the loopholes.

If the yard is surrounded by coach houses, stables, &c., they must be prepared in the same manner as for the house, according as time and means permit, that is to say, we barricade the openings, pierce loopholes, and contrive some means of communication between them, so that the taking of one does not entail the loss of the other. An enclosure wall must be loopholed, even in two rows, if high; the loopholes pierced at one foot from the ground are the most dangerous to the assailant; a little ditch is dug inside to serve as a banquette. Very rarely can a wall of this kind resist cannon, but it can be strengthened with earth banked against it. A hedge replaces palisades, and if it is higher than a parapet, we make a banquette.

The exterior part must not be intrenched before being sure of the means of defence for the house, and unless the force of the detachment enables it to be done.

With a garden enclosed by walls, the same precautions are taken as with a yard.

When the house is situated on level ground, it may be surrounded at eight or ten yards by an intrenchment with ditch and parapet, forming a first enceinte, or by abattis or palisades, according to the importance of the post.

(158). Farms.—An isolated farm house differs from other houses, because the enceinte is more extended; it has generally numerous buildings about it: barns, stables, workshops, &c., surrounding several yards. These premises, almost

always situated in the centre of the ground to be cultivated, often occupy a good position in a line of battle, in which case we intrench in them several battalions and some artillery, so as to resist several attacks.

More frequently still, an isolated farm house is occupied by a detached post; and all that we have said concerning a house is applicable to it, or at least to a great part of it. Sometimes a farm house is an old country or pleasure house, or is composed in part of the ruins of an old castle, of which some great walls are remaining, capable of making a good redult. The first examination of a locality ought to determine which part of the building will be reserved for the defence, according to the force of the detachment; this part must be isolated from the buildings, and intrenched in the manner explained above.

A convent or an old abbey may be ranged in the same category.

Churches.—In many countries churches are to be found isolated, when, for instance, the houses of a village are dispersed, or when it serves for two villages. They are also sometimes in the centre of the place, but are rarely so situated that they can be approached under cover. They must be isolated, even from the rectory house, if this is likely to damage the defence.

A church almost always unites more defensible qualities than a house; it is, therefore, a good post. Churches are rarely commanded, and are generally surrounded by a cemetery, which often forms a good intrenchment. Still, the cemetery must be abandoned if the detachment is too weak. Houses and trees in the neighbourhood furnish means of defence for the church.

A large church can be defended by a weak detachment, because the troops are not subdivided. The walls are stronger than those of private houses: they almost all resist cannon; loopholes are pierced between the pillars. Churches in the shape of a cross can give flank fire.

Amongst the means of intrenchment given for houses, those for the church must be chosen for the interior and exterior, according as they agree with the ground. Rows of loopholes can be multiplied; the galleries and pulpits serve very usefully as intrenchments; stones and paving stones must be carried to the top of the church, to be thrown down on the enemy during his attack. The choir, choir gallery, and the vestry must be individually retrenched, and made to communicate with one another. The chairs and seats serve to make good barricades. The steeple will be the last retreat in which the garrison can defend itself.

Castles.—We meet frequently, especially in mountainous countries, with very strong old castles, of which some are abandoned and in ruins, and of course uninhabitable, and others more or less in a state of preservation. These castles are sometimes the best posts to defend.

Abandoned castles are for the most part invaded by the neighbouring forests;

they are surrounded by wide and deep ditches; their walls are very thick, and are pierced with numerous loopholes, and surmounted with machicoulis. These forts have often several enceintes, flanked by a strong tower, and closed by double gates, some of which are still furnished with a portcullis; but the walls are damaged, the vaults broken in, the ditches partly filled up, and the interior parts without fastenings and filled with rubbish. Nevertheless, the walls present such a solidity, that by means of a few dispositions, a vigorous resistance may be made; and in order to ensure this, clear away the foot of the breaches, barricade the openings and issues, take away the rubbish from the towers and rooms, make sure of some shelter, open the battlements and embrasures, entrench the interior buildings, and make a reduit of the keep.

Those castles which are preserved are for the most part inhabited, at least at certain seasons. They have besides, drawbridges, armouries, falconets, lances and other arms to be made use of; but in a great number of them the ancient form is altered, at least in the exterior: groves and gardens have replaced the great esplanades, from which one could see far. These gardens, and all other objects favouring the attacks of the enemy, ought to be destroyed, in order completely to isolate the fort. Fortified castles are not always advantageously situated: those placed on the summit of a mountain, far from any frequented passage, do not hinder the movements of the enemy; a detachment of a few hundred men shut in, far from the marching columns, cannot, indeed, disturb them. Therefore, such castles ought not to be defended, unless their position compels the enemy to attack them, or to alter the direction of his march.

Modern castles are great country houses with numerous dependencies, whose disposition is generally little advantageous for entrenching. If, however, it is of importance to occupy the position, if the detachment is sufficiently numerous to effect this, and if part of the buildings is also favourably constructed (for instance, surrounded by water or a great terrace) we must not hesitate to sacrifice all the rest, and make the works suitable for a strong resistance.

Isolated Mills.—Wooden wind mills are not capable of defence, but stone mills often make a good defensible post for a few men. Generally situated on an eminence, these mills, in the shape of a round tower, and perfectly isolated, can be easily put into a state of defence: it will be sufficient to pierce some loopholes, to barricade the doors and windows, and to take away the roof and sails. The rubbish and wood serve to make scaffoldings for the interior.

Water mills belong to the class of houses; however, they deserve particular attention, according to the watercourse they are on, and the importance of the passage when there is a bridge.

Mills placed on a rivulet are hardly capable of defence, unless their construction is really good, and the bottom of the vale is marshy; but mills which have a weir

in the river generally give at the same time passage to a road; they are frequently of a solid construction, and have several wheels; they form, in a word, a pretty large establishment, which offers advantages for defence, especially if the water-course is a defensive line. By stopping the water, inundations may eventually be produced.

Woods.—Natural features are of great utility for the defence of a wood; thus a ravine, a marsh, ponds, a river's banks, &c., can be made to render great assistance if they are conveniently situated.

A wood of little size, especially if it rests on these obstacles, could be defended by ordinary means, that is, by cuttings in the trenches and roads, and by abattis so disposed on the edges of the wood, that the enemy could not destroy them, and that they may be flanked from other parts of the position. But in a forest, a detachment could not defend itself without choosing a very advantageous place, easy to be isolated or intrenched, according to the locality. If time or means are wanting to dig a ditch, and throw up intrenchments of earth capable of a good resistance, a work could be constructed with trunks of trees, vertically disposed in the shape of stockades. This work could be closed, and means of retreat provided for; the tops of the trees would serve to form a line of abattis around the entrenchment.

Defiles.—The most advantageous point of a road to defend is its passage across the different accidents of the ground which permit the enemy neither to deploy nor to turn the position from a little distance, as for example, between steep heights. We must commence by reconnoitring these heights, and their accessible parts, and ascertain that they cannot be turned without making a long circuit. This done, the commander will occupy the heights with small posts, that intrench themselves according to the locality, making use of the wood to construct abattis, and of the hedges, houses, and walls; or if the ground is open, he will dig ditches and cover them with breastworks. He must build up in the defile works capable of a certain defence, such as redoubts flanked by intrenchments at the foot of the heights, connecting the defence of the redoubts with that of the posts established on the heights. Means should be provided for retreat from all these posts. If time fails for the execution of such works, the interior mouth of the defile and the crest of the heights should be occupied, to flank the passage: this is covered by strong abattis or any other obstacle at hand, and is momentarily obstructed.

If the defile can be turned from a little distance, the intrenchment must be strengthened so as to resist reverse attacks.

(159). When an officer has to put a *village into a state of defence*, his first care should be to make a *reconnaissance* of the village and its environs. He should direct his attention to the disposition and nature of the buildings, to the number

of men the village can contain, to the roads by which the enemy may come, to the resources which may be obtained from the village itself or from the neighbouring woods. A sketch of the position will enable him to judge of the ensemble of the village, and will greatly help him in forming his scheme of defence. As several days will most likely be necessary to intrench the village, he will seek for a *good post*, an isolated building, a hillock, &c., in the direction from which the enemy is expected; this he will fortify by abattis, barricades, &c., and employ it to *hold most* of his detachment at night, and the non-working party during day.

The *approaches* are cleared of any cover which the enemy might make use of; isolated buildings, walls running parallel to the enceinte, trees, &c. are felled down, ditches are filled up. Abattis are formed. The roads, dams, causeways, &c. are rendered impracticable, by coupures, entanglements, or by other means.

The *enceinte* is next organized. It is formed by the buildings, walls, hedges, and is completed wherever necessary by stockades, tambours, or even by ditches defended by abattis. Barricades flanked by the adjacent houses close the streets that lead into the country, and either gates or timbers prevent the entrance by such canal or sewer as may exist. Field works, such as *flèches*, are constructed to flank the points of attack. If possible, a ditch should be excavated for this enceinte.

When time can be spared a second enceinte, or even a third, is similarly organized, and care is taken in every case to insulate the enceinte from all buildings, (since the destruction of this by the enemy's artillery might injure the defenders), and to insure a good flanking by means of tambours, &c.

A *reduit* sufficiently large to accommodate the garrison is prepared in the manner described for houses, churches, &c. It should be isolated from other buildings, and when there is no time to spare, it is advisable to organize the reduit before the enceinte itself.

Besides the enceintes, it is advantageous for the defence to subdivide the village into portions, by turning into use the walls, hedges, &c., so as to form a continuous intrenchment from the reduit to the circumference. One of these portions being taken, the defence of the village will continue.

All the streets, bye-streets, &c. which are not required by the defenders are barricaded, to prevent the enemy from turning the position; but a few debouches are prepared on the flanks or rear for the egress, and are flanked by houses, &c.

If the garrison has guns, they are placed at the points of attack, or on such spots that they can pour a flank or slant fire on the enemy's advance: epaulments and platforms are prepared in several places for that purpose. If the enemy has artillery, the wooden houses are destroyed, and the thatch of the others is removed for fear of fire.

When a rivulet traverses the village an inundation contributes powerfully to its defence. (117.)

Villages are met with, where the enceinte thus constructed would not be susceptible of a good defence, either on account of its general outline or the nature of the ground in front of the position. It is then preferable to surround it by a continuous intrenchment. If the village is built on the sides of a hill, it could not be defended with a mere enceinte; in this case an enclosed work is thrown up on the hill, and serves as a reduit: it is either a redoubt or a fort, and sufficiently strong to offer the same resistance as that which is expected from the village.

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CHAPTER X.

ATTACK AND DEFENCE OF FIELD WORKS.

(160). The attack of field-works may be carried on in two different ways, either by *surprise* or by *open force;* but in every case a careful reconnoissance of the enemy's position is indispensable.

The chief of a detachment entrusted with the attack of a military post must ascertain the nature of the ground occupied by the enemy, he must know the roads that lead to it; the outline, profile, and armament of the work; the number and description of the garrison; the amount of ammunition and provisions at their disposal; the nature and positions of the obstacles, &c. A reconnoissance made by himself or by some intelligent officers will complete the information which may be derived from maps, spies, deserters, and from the inhabitants who have been employed in the construction of the work. If the post is a building or a village, similar knowledge of the dispositions of defence must be obtained.

Besides this information, the commanding officer will ascertain the manner in which the service is performed inside and outside the post; how many sentries there are, how often relieved, and where placed; the hours of meals; by whom the post is commanded; the age of the commander, qualities, and habits; whether he or his troops have defended a field-work before; and whether they expect support, &c., &c. From all these data he will decide as to how the attack may best be conducted.

(161). An *attack by open force* is the only one that can be recommended against a work properly guarded.

During a battle, for instance, an attack by surprise would be impossible. This sort of attack may also be resorted to.

When the enceinte can be easily escaladed, when the enemy is short of ammunition, when the garrison is weak or composed of recruits, when their chief is inexperienced or timid, and lastly, when the approach of a reinforcement compels the assailant either to carry the work or to retreat.

If the work has but a small profile, and is ill provided with necessary means of

defence, such as an intrenchment thrown up in great hurry, the attack with fixed bayonets may prove the least dangerous and the quickest; but it will be necessary in ordinary circumstances to prepare the assault with artillery.

The detachment intended to carry the post is generally subdivided into four parts, 1st, a column destined for the serious attack; 2nd and 3rd columns for false attacks; 4th, a reserve.

Each of these columns is preceded by skirmishers, and by a working party provided with all the necessary tools to destroy the obstacles; when possible, scaling ladders are brought by a special party (194), and, when necessary, fascines are carried by the working party to fill ditches, &c., with. The chief of each column always receives instructions as to what he will do both in the event of success or of failure.

The artillery opens fire at a distance to dismount the guns in barbette; at 600 yards it ricochets the faces, and when it has silenced the artillery of the defenders, it approaches nearer to destroy the parapet, to make a breach, and to throw confusion inside the work by a shower of shells and canister.

Under the protection of the skirmishers who fire at any one standing on the banquette, the working party destroy the obstacles, as will be explained hereafter, and the columns follow.

In order to divide the attention of the enemy the false attacks proceed first, or at least simultaneously, and march either against the rear, or some point where the enemy least expects them, the serious attack beginning as soon as the others are engaged, and advancing against some undefended angle, or some point weakly garrisoned, unprovided with ditch, &c.

Arrived within range of grape shot and musketry, the columns quicken their pace, reserve their fire in order to save time, and leave the artillery and skirmishers to answer the enemy's fire. They reach the counterscarp, and descend into the ditch, if it has been cleared of obstacles; if not, they keep up a strong fire on the defenders until the working party has completely destroyed the palisades, &c.

The reserve replaces them on the counterscarp.

The men spread in the ditch apply their scaling ladders, climb the slopes, or enter by the breach, or the embrasures, and give the assault. They form on the superior slope, fire a volley, and charge the reserve. If success crowns their efforts, they hasten to support the other attacks.

The reserve is ready to repulse any sortie which the enemy may attempt, and to support the storming columns should they be repulsed; it also protects the retreat.

As a general rule, the force of a column of assault should be $\frac{1}{4}$ of the force of the garrison: the reserve, more numerous still, should consist of old soldiers, steady under fire, and should contain some cavalry to charge the sorties. Should

the garrison expect some reinforcement, let it be understood that a fifth column must be told off, to oppose it and prevent its arrival.

When the work is conquered, dispositions are at once taken against offensive returns: the parapet is repaired on the side where the enemy is expected, and in the case of a work opened at the gorge, a parapet is constructed across it.

The retreat is also rendered secure and the work made unfit for the former possessor by filling the ditch and destroying the parapet at the point where the attack has been made.

As for a village, before entering it the artillery should ricochet the streets and set fire to the houses, whilst the infantry occupies those which have not been destroyed, and compels the defenders to leave them. Without these measures, offensive *returns* may be made which would endanger the retreat should a further attack on the redult prove unsuccessful. Some rockets fired through the loop-holes are sufficient to smoke out the defenders.

(162). An *attack by surprise* has a chance of success when the garrison, feeling perfectly secure, neglects the ordinary rules concerning sentries, patrols, &c.: it is attempted against a work too strongly occupied to be attacked otherwise, and secrecy is one of the most important conditions for effecting a surprise. Some false news skilfully spread, and some false movement that will throw the garrison entirely off its guard, will contribute to the success of this kind of enterprise. However, it is a dangerous operation, the assailant may suffer heavily, and be himself deceived by the apparent security of his enemy; and, in general, such attacks seldom succeed, especially against works well provided with obstacles.

The best time to make an attack by surprise is about two hours before day-break. The corps is subdivided into one strong column for the serious attack, two small ones for the false, and a reserve.

The columns are accompanied by guides and interpreters, as well as by a working party and scaling ladders. The interpreters answer the "*qui vive;*" and, if the weather is favourable, the columns may reach the counterscarp without being seen, but in general it will be necessary to attract the attention of the defenders by pushing the false attacks; the darkness and confusion helping, it is probable that all the garrison will engage; and at the moment when they are thus engaged, the serious attack, vigorously made, can be attempted.

The destruction of the obstacles is effected, in both kinds of attack, by the working party. Although the abattis, palisades, fraises, &c., are not capable of resisting artillery, yet it is difficult to open a practicable passage during the short time the attack lasts: shells and shot may injure them here and there, but not sufficiently; and as it seldom happens that they are exposed to view, it is found more expeditious to entrust their destruction to the working party.

Abattis are destroyed with the axe; and the trees, when small, are removed out of the way by means of ropes; if they are large, the trunks are left.

Chevaux de frise. The spikes are cut with the axe, the beams sawn, and the chains that connect them broken with the picks.

It is sometimes recommended to set fire to the wooden obstacles, by means of fascines covered with tar, but it is a slow process, although a safe one: *palisades*, *stockades*, and *fraises* are more difficult to destroy. They are demolished either with the axe, or by means of powder. Some 50 lbs. of powder are placed in a bag, and secured to the wood by means of a nail and gimblet; or a stout sleeper is placed along the foot of the palisades, and a few bags, containing about 20 lbs. of powder, are placed before it, and secured by another sleeper covered with sand-bags, and maintained in its position by a few balks propping it up on the foot of the counterscarp.

Stockades and gates are too difficult to cut through with the axe, and it was formerly customary to burst them open with a *petard*, which is a vessel made of iron, filled with powder, and secured by a gimblet or otherwise; it is fired by means of a fuze; but a bag is preferable, because the petard will frequently make only a hole.

The *small pickets* must be destroyed with the axe.

Whilst these obstacles are being removed or destroyed, the working parties also prepare ramps for the columns of attack in the glacis that cover them, as well as in the counterscarp; and, if necessary, they open a trench across the escarp and parapet. If fire were to be set to the obstacles, these ramps could not be cut until the fire had gone out. It is proper, despite the danger to which they are exposed, to have strong working parties, because the obstacles are more rapidly destroyed, and the defenders have less time to ascertain the range: the men are recommended to avoid forming groups; they cover themselves with fascines when they suffer much from musketry, or they may, by firing heaps of wet straw, properly disposed, be concealed by the smoke.

Military pits are covered with planks, fascines or ladders, or they are filled up, a process which is sometimes more speedy.

Crows'-feet are swept by means of branches of trees, or what is better, the ground is covered by fascines placed close to each other perpendicularly to the direction the column will follow.

Wet ditches and inundations are serious obstacles in the field; the former are filled with fascines, stones, &c.; but the latter present far greater difficulties, and require those means which are employed to overcome permanent fortifications.

(164). The officer sent to occupy and *defend* a fieldwork should begin by ascertaining the purpose for which the intrenchment has been thrown up, and by making himself thoroughly acquainted with its relation to the ground or other works

which it has to flank. And for this duty a previous knowledge of fortification is necessary.

He will make a reconnoissance of the exterior ground, so as to know from which direction, or by which road the enemy is likely to come, what cover he may obtain, &c. The distance from the crests to the important points are measured in order to give proper sight to the guns, and to insure the efficiency of the fire.

At the same time, he will divide his force into four parts; one to furnish the guards and patrols, another to work in order to complete or improve the means of defence; the two other reliefs rest. On no account will he relax in watchfulness: sentries are, therefore, placed inside the work at each salient, and outside in the directions from which the enemy may be expected; at night, and at daybreak, patrols and detachments are sent in every direction. The patrols ascertain whether the sentries are on the alert or not, and carefully search the houses, hollows of ground, &c. The small detachments proceed further, and collect such information about the enemy as they are able to obtain. Should a sentry, patrol, or detachment fall in with the enemy, they must fire to give the alert, and withdraw without fighting.

He will next give his attention to the mode of defence; each part of the garrison must know exactly what duty it has to perform, and where to repair in case of attack. The reserve, consisting of a third of the whole garrison, is told off, and has also its assigned post.

The working party, in the meanwhile, constructs such additional obstacles as the resources of the locality permit, and if the work is likely to be exposed to a fire of artillery, some traverses are constructed to protect the guns and shelter the reserve from the splinters of shells.

When the enemy approaches, great sagacity is necessary to distinguish the real from the false attacks; and coolness is not less indispensable to direct the defence. The men are kept on the slopes of the banquette as long as the enemy is not within easy musketry range; artillery should not attempt to fire at the enemy's guns, because it will generally get the worst of the contest, it is preferable to charge the guns with grape, and wait until the columns are within 300 or 400 yards. Such fire may throw the ranks into utter confusion, in which case a sortie made *à propos* will repulse the attack. As soon as the enemy comes within 200 yards, the men ascend the banquettes, and open fire. The officers should see that they do so in no hurry, since a well aimed fire will do more injury than a rapid one.

If the work is intended to flank some other intrenchment in front, the garrison should do so conscientiously, even at the risk of being lost (57).

It would be impossible to prescribe what to do in the thousand eventualities that may occur. All the obstacles will be of little avail unless the garrison is

determined to fulfil its duty. "Fight to the last, regardless of danger!" ought to be the motto of all troops engaged in the defence of an intrenchment; "self-devotion!" that of the commanding officer.

Steady fire is kept up against the enemy whilst entangled in the obstacles; grenades or shells are thrown into the ditch; vigorous sorties are made to repel the attack, or if these are unsuccessful, bayonet and steel must resist the assault. When all is exhausted, and only then, the reserve makes a last effort; and if the assailant cannot be repulsed, the retreat begins.

In the defence of military posts, such as villages, the same measures are taken. Artillery opens fire at small range, changing its position whenever necessary; cavalry keeps on the flanks, ready to charge the assaulting columns; whilst the infantry is divided into three parts: one defends the enceinte, another disposed in small platoons at the most convenient points is ready to support; and the third, forming a reserve, occupies a central position, ready to rally the advanced troops, repulse the enemy wherever he enters, and protect the retreat.

The defence of a village is not ended if the enemy has forced the enceinte, far from it: the troops assume a new disposition, they occupy the houses, coupures, barricades, &c., and dispute the ground inch by inch, with such determination that when the enemy has overcome all obstacles and attacks the reduit, his losses may have been such that he is no longer sufficiently strong to conquer, and the garrison may even, by an offensive return, recover possession of the village.

Coolness and great decision are essential qualities in the officer; his example may decide the day; and, when commanding the evacuation, and, last of all, abandoning the post, he should be able to say, that "all is lost, save honour!"

Fieldworks and fortified posts are not generally intended to make a defence of long duration; a day, or half a day, is considered a fair time; and it has often proved to be of incalculable value. We have already mentioned the work of Montenotte, which, for 24 hours, stood the repeated attacks of 12,000 Austrians, and thus gave the victory to the French. In 1793, the Dutch army was saved by the resistance of the post of Werwick on the river Lys. The same year the post of Turcoing defended itself a whole day, and thereby prevented the French from attacking the English. The great redoubt of Fleurus (1794) saved the French army from a defeat. The vigorous resistance of the Austrian works at Jemmappes; of the Russian redoubts at Borodino; and that of the hamlet of Hougoumont, at Waterloo, &c., are well known.

CHAPTER XI.

MILITARY BRIDGES.

(165). *Military bridges*, are those bridges which an army in the field can speedily construct, and the materials of which can be transported. As any floating material may serve to form such bridges, there are a great many sorts of them. But whatever sort may be proposed, the preference will be given to that which possesses most of the following qualities: simplicity and capability of rapid construction; applicability to several purposes, as fitness to serve for boats as well as for a bridge, and security from destruction by the enemy; great buoyancy and stability; facility of construction, of reparation, and of management on water, security from destruction by heat, ice, or other natural cause; small cost of outlay at first, and of keeping up afterwards.

Military bridges may be divided into 2 classes:—1st. Those which are prepared in time of peace and follow the army. 2nd. Those which are constructed with any material found on the spot. Those of the first description bear the name of *pontoon* bridges.

A pontoon is a floating pier, the form of which varies with every service: in the British army the pontoons in use are those invented by Colonel Blanchard: they have replaced those of General Pasley, which were of copper and had the shape of a boat. Before these, cylindrical pontoons of wood of the invention of Sir James Colleton, had been employed in preference to flat-bottomed boats.

(166). The *large pontoon* bridge is composed of four parts; the pontoons, the saddles, the balks and the chesses.

The pontoons are hollow cylinders with hemispherical ends, 22½ feet long by 2 feet 9 inches, made of tinned sheets of iron. The sheets of metal are framed

Fig. 365.

round some light wheels of tin which have small tubes for spokes, and are connected by a hollow cylinder which runs through the whole length of the axis.

Fig. 366.

The interior is divided into distinct and water-tight compartments by partitions. Each end has a strong iron ring to assist in the conveyance: some plugs are screwed at various parts to permit the insertion of a pump in case of a leakage. Four rows of sunken handles round the outside serve to lash the saddles.

These *saddles*, or *gunwhales*, or *gunnels*, are framings of fir 12 feet by 1 foot 2

Fig. 367.

inches, and 3 inches thick. One is placed lengthwise on the centre of the pontoon, and is secured to its handles.

Balks are strong rails of timber 14 feet by 5 inches, and 3 inches thick, they are placed in position from saddle to saddle, to which they are secured by iron pins. There are 6 of them for each pontoon.

The *chesses* form the flooring of the bridge: whole chesses consist of three fir planks connected underneath by four cleats, and are 11 feet 5 inches by 2 feet 1

Fig. 368.

inch, and 1½ inch thick: half chesses of same length and thickness, but 1 foot and half an inch only wide are placed over the saddles, to afford access to the pins, &c. The chesses are laid across the balks to which they are secured, by rack lashing two *side pieces* along and over the extremities of the chesses.

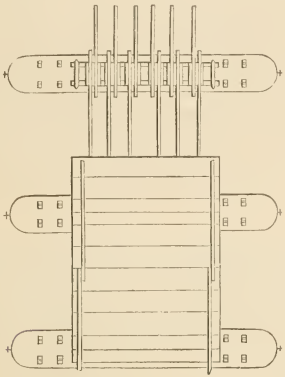
Fig. 369.

A rack stick is a small picket, 18 inches long, to one end of which is fastened the lashing or rope about 8 feet long. A loop is formed with the lashing round the side piece above the chesses and the balk underneath; the rack stick is then placed in the loop and turned until the lashing compresses firmly the side piece upon the chesses.

A *raft* consists of two pontoons with their superstructure, viz. two saddles, 12 balks, 10 chesses, 4 half chesses, 5 side pieces, and their stores of lashings, oars, anchors, &c. It is conveyed on a pontoon carriage, total weight including carriage about 45 cwt. 39 lbs.

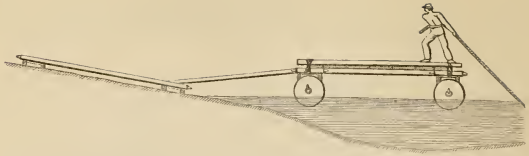
The buoyancy of a raft, its weight deducted, is about 77 cwt., half of which is a safe load. The pontoons sink from 7 to 8 inches under the weight of the bridge. At the full interval of 24 feet from centre to centre of raft the bridge can carry infantry 4 deep, or cavalry 2 deep, or light artillery. At intervals of 16 feet it will carry heavy field guns; and a raft of three pontoons, at close intervals, will carry the heaviest ordnance.

Fig. 370.



There are two methods of constructing the bridge. In the first, which is called *booming out*, a frame of two saddles, connected by their balks, is prepared on shore: a pontoon being launched, the frame is lifted up, and the pontoon is brought under the first saddle, and fastened to it; in the meanwhile, the balks of another frame are bolted to a third saddle, the bridge is boomed out, and a second pontoon is fixed under the second saddle, and so on. The chesses are laid across by the crew, six men per raft, standing on the balks and pontoons. The bridge is kept in its proper position by means of rope secured to anchors, and held by the crew; it is rigid in the direction of the current, and the balks of the two extreme pontoons are pinned to sleepers firmly secured on shore.

Fig. 371.



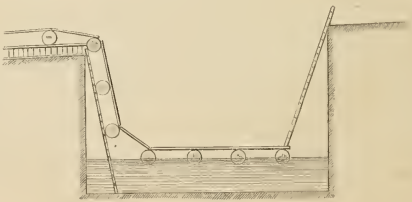
In the second method, the rafts are formed separately and kept close to the shore, each of them carrying sufficient superstructure for an extra bay. A *bay* is the length of bridge corresponding to the space between two pontoons from centre to centre. The odd number rafts form what is called the mooring division, and they are rowed to their places across the river, at distances apart equal to the length of three bays. The even number, or reserve division, move up the stream and take position in the middle of the intervals, thus leaving a bay on each side. These bays are then completed with the superstructure carried on the raft.

(167). In the small or infantry bridge, the pontoons have conical ends, and measure 15 feet by 1 foot 7 inches. The saddles, 8 feet 4 inches by 9 inches, and

Fig. 372.

3 inches thick, are fixed to the pontoons by means of girths. The balks are 6 feet 6 inches by 5 inches, and 3 inches thick; the chesses are 8 feet by 1 foot 4 inches, and 1½ inches thick. A carriage can convey five pontoons, and all their appurtenances, the total weight being 21½ cwt. The buoyancy of each pontoon, weight of superstructure deducted, is about 13½ cwt. At intervals of 5 feet 4 inches, this bridge will carry infantry 3 deep, or light artillery. It can be constructed as the large bridge, or it may be entirely put together on land, and be carried to

Fig. 373.



the water by men placed two at each end of every pontoon. It is very light, and if the chesses over the saddles have been previously removed, it will bend upwards or downwards to any angle, so that it may be passed over scaling ladders down the countersearp of a fortress.

(168). This system of pontoons has not yet passed through the ordeal of a campaign, and it is questionable whether it would prove serviceable or not. The pontoons of continental armies are capable of serving both as floating piers and as boats to ferry troops over, whilst those can only be used as floating piers; it is true that they cannot be upset by swells, but they are made of a material liable to rapid decay, their inside cannot be seen so as to secure timely repair, they can only be emptied by pumps, and, what is worst of all, the bridge is liable to great undulatory motions in the direction of its length, motion which caused a serious accident when a bridge of this kind was constructed over the Thames at Chobham.

Macintosh india-rubber pontoons have been tried and found worthless. Two new pontoons have lately been invented, and it is very probable that for the future the Blanchard's floats will be superseded.

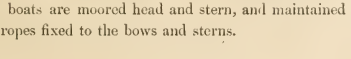
The first, called *Francis's* corrugated metallic wagon, is used in America. It is a wagon the body of which, made of corrugated copper or iron, is easily detached, and can be used as a boat: two of these rectangular water-tight bodies joined form a raft fit to carry field artillery; four of them will bear heavy ordnance. They are very strong, difficult to upset, and form a firm and buoyant bridge.

The other kind of pontoons has been proposed by Capt. Fowke, of the engineers. Each pontoon is formed of a wooden skeleton, over which is strained strong canvass rendered waterproof. It can be used as a boat, and is water-tight. It has a buoyancy nearly double that of the service pattern, whilst its weight is only half. The transport is also greatly simplified.

The second class of bridges is numerous, and may be subdivided into floating, fixed, and flying bridges.

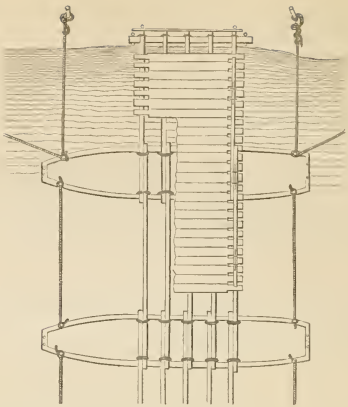
The *boats* which the vanguard collects on the river may replace the pontoons. They should be as nearly as possible of the same size, in order to avoid irregularity in the flooring of the bridge, any difference being made up with frames or

Fig. 374.



trestles. The boats are moored head and stern, and maintained in their position by timbers or ropes fixed to the bows and sterns.

Fig. 375.



Cables have occasionally been employed to replace the balks when tides or rapid rises would have endangered the bridge. In a bridge made across the Adour in 1814, the floor was supported by five cables lashed in the notches of a sleeper, placed on the deck of each vessel. They were kept tight by capstans

Fig. 376.

and gyn tackles. This bridge never gave way during the two months it stood.

Other means have been resorted to to remedy the inconvenience of sudden

Fig. 377.

rises: the butment has been made of a trestle with moveable cap, or of a sleeper moveable round two trunnions.

(170). *Casks* may serve to form floating piers. They are placed bung-hole uppermost, side by side, and secured to two strong balks, placed parallel to one

Fig. 378.

another about six inches from the end, by two slings three inches in diameter.

Fig. 379.

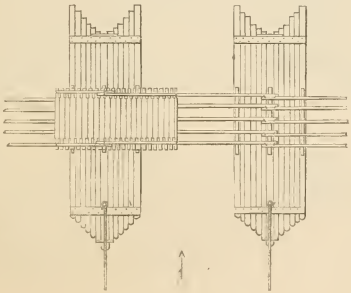
Smaller ropes, called braces, are attached to the slings between every pair of casks, turned round the balks, and again lashed to those of the opposite side, and firmly secured.

Fig. 380.

The casks may also be enclosed in an open frame of woodwork. These piers are excellent, but they should be at least 20 feet long.

(171). *Rafts* made of trees bound together and stiffened by cross and diagonal braces, are not so good on account of their small buoyancy. Their chief advan-

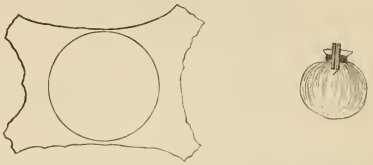
Fig 381.



tage is that they cannot be destroyed by the enemy's artillery. Their length should not be less than 45 feet. Fig. 381 shows the disposition of the rafts constructed in the French service.

(172). *Floats* may be made of the skins of the animals killed for the army. An ox hide may be made to form a float capable of carrying 300 pounds. Each skin is cut into a circle of from 5 to 6 feet in diameter, and its edge is gathered round a short tube, to the inner end of which a leathern valve is nailed. It is

Fig. 382.

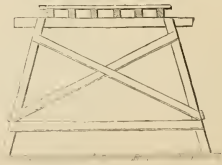


inflated with bellows. The back part of the skin is not good, and should be tarred. These floats are used as casks, but they require re-inflating every ten or twelve hours. They should not be employed when the velocity of the current exceeds 6 feet per second.

(173). *Trestles* bridges are constructed, when floats cannot be procured, for shallow rivers having a firm bed, and the velocity of which is not much above 4 feet per second. Trestles are made of any material found on the spot, and are secured in their place by putting stones or shot inside their legs, and by lashing their heads to a rope stretched across the river. An additional leg may be given to the end down the stream. The usual dimensions for the cap piece are from 12

Fig. 383.

Fig. 384.



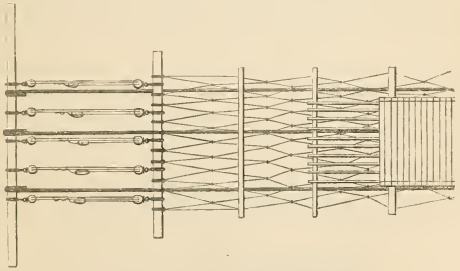
to 15 feet long, and from 9 to 12 inches square. The legs are made of timber, from 6 to 9 inches square, the distance between the feet being about half the

height. The braces may be scantlings 8 inches by 2. They are never higher than 10 feet, and they are placed from 10 to 15 feet from centre to centre.

(174). *Piles* are used when the river is rapid, muddy, and wide, more especially if the bridge is intended to stand a long time. For the passage of infantry alone, and in shallow rivers, the piles are driven in by means of heavy mauls; but when they are destined for artillery, they must be driven in by a monkey made of a heavy shell filled with lead. The piles, 1 foot in diameter, pointed and often capped with iron, are buried 9 feet, cut to the same level, and fitted with a head piece on which the balks are placed. The number of piles in each row varies with the width of the bridge; they are usually 3 feet apart. The rows or piers are as far apart as the length of the balks will allow.

(175). *Rope* bridges are not recommended; they are costly, cumbersome to carry, and liable to destruction through alternating dampness and dryness. They have nevertheless been frequently employed. As early as 1515, the Swiss constructed a rope bridge across the Po near Casale, over which they transported their artillery. The French did the same in their campaign in Italy in 1742, and in 1792 there was a regular rope bridge in the service. During the Peninsular war both French and English had recourse to them. In 1810, the French having destroyed an arch of the bridge of Alcantara, Colonel Sturgeon re-established the communication with ropes. This bridge consisted of a network of rope fixed to

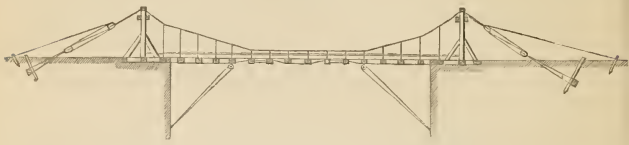
Fig. 385.



two moveable beams, stretched at each side of the arch by five blocks of pulleys fixed to a strong sleeper secured in the masonry. This network was supported besides by three hawsers stretched tight between the two sleepers, and prevented from oscillating by the guys underneath. Over the network cross beams rested, which supported the balks and their chesses.

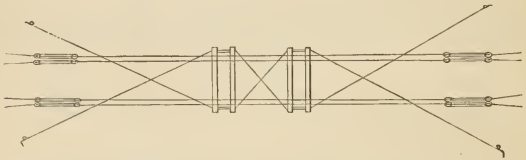
In a system successfully tried at Metz in 1827, the superstructure consists of transversal beams supporting the balks and chesses. These beams are borne by suspending ropes attached to four strong cables, two on each side, passing over horses 12 feet high, and stretched by means of 8 blocks of pulleys fixed to strong

Fig. 386.



beams, which are secured in the ground at a depth of 6 feet. Lateral oscillations are prevented or at least diminished by two ropes, crossing each other several times under the flooring; they are fixed to the ground and maintained in their

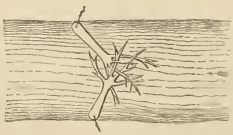
Fig. 387.



position by rectangular frames, which have pulleys at their angles on which the ropes run. The vertical oscillations are prevented by guys underneath.

(176). A large river is not likely to arrest an army, because the necessity of providing means of passage has been foreseen, but a small stream, a canal, a broken arch, &c., may cause a serious interruption in the march. In such a case every available means becomes valuable. A small detachment may pass over a

Fig. 388.



tree felled from the bank, or over one felled from each bank: the branches entangling themselves secure their position, and the axe soon cuts a passage.

A few trees lashed together into the form of a raft, and secured by one end to the bank, will, when set afloat, be carried across by the current itself, and serve as a bridge or for the foundation of one.

Fig. 389.

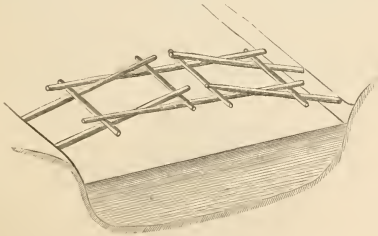
A lever bridge is made by burying the trees in the banks so that the parts buried overweigh the rest, and if the trees are too short to meet, their extremities

Fig. 390.

Fig. 391.

are connected by short ones made fast to them. In 1811 the French in this manner repaired 20 yards of the bridge of Moreilla on the Alva.

Fig. 392.



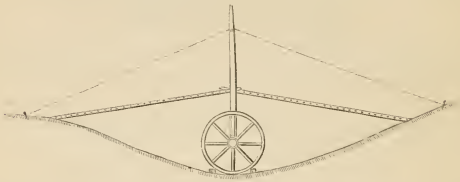
Young trees may form bridges of the rustic order.

When the depth of the water is not more than 4 to 5 feet, wagons may be employed instead of trestles.

Fig. 393.

A gun limber placed vertically and secured by ropes, may support frames or ladders on which planks laid across form a flooring.

Fig. 394

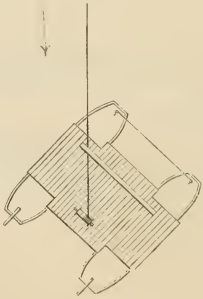


Gabions of a large diameter have occasionally been employed: they were laid horizontally and covered with fascines.

(177). *Flying bridges* serve to convey troops across rivers on which a floating or fixed bridge would seriously interfere with the navigation. They also serve to pass detachments over, previous to the construction of a regular military bridge. They are especially adapted for rapid rivers, and are very common on the Rhine and Danube.

A flying bridge generally consists of a raft of two boats, or of one boat only,

Fig. 395.



anchored in the middle of the river, with a cable usually equal in length to $1\frac{1}{2}$ the width of the stream. This cable strongly secured up the stream, is supported by

Fig. 396.

Fig. 397.

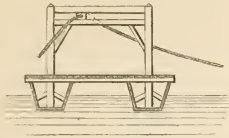
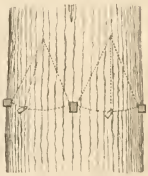


Fig. 398.



buoys or boats. It is attached, near the stern, to a windlass, and traverses on a horse erected near the bow, at about $\frac{1}{3}$ of the length of the raft. The rudders give to the raft a proper direction. Floating wharfs are constructed on each bank to facilitate landing and embarking.

If the river is very wide, a wharf is fixed in the middle, and two flying bridges are employed.

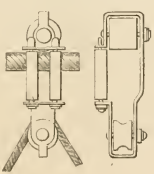
The angle which the raft makes with the current varies with the length of the mooring. When the cable is only half the width of the river, the angle at departure is 90°, that of arrival 0°; when it is equal to once the width, these angles are respectively 68° and 40°; and when the length is $1\frac{1}{2}$ the width, they are 64° and 44°. As a rule the raft should always make an angle of 45° with the cable.

(178). The *trail* is a raft warped across a stream by means of a chain or rope

Fig. 399.

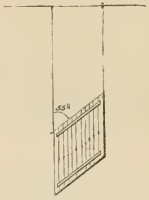
stretched from bank to bank. A rope is attached to the raft or boat, and by means of a peculiar pulley, called *traveller*, slides along the chain. The current

Fig. 400.



causes the raft to pass when its surface forms an angle of 55o with the direction of the stream. It is preferred for rapid and moderately wide rivers. A trail may consist of a raft having the form of a rhombus with angles of 55°, attached to the chain by two ropes.

Fig. 401.



(179). *Ferries* are flat bottomed boats with moveable gangboards. Such a boat is carried across by means of a rope stretched across the river, on which the men pull. This rope may partially dip in the river and rest on two supports fixed to the boat. In 1796, at Placentia, Napoleon conveyed 500 men and 50 horses at a time across a ferry.

(180). To complete this chapter, we may add a few words on the selection of the point of passage and on the details relative to the calculation necessary for the construction of a bridge.

When the passage of a river is likely to be disputed, the best position for a bridge is on a bend, presenting its concavity towards the enemy, because it affords greater facility to concentrate fire upon him, more especially if the opposite bank is commanded. There should be in front sufficient space to allow the army to take position after its passage. The bank should be high, because in sudden rises shallow banks cause rapid alterations in the width of the river, but high banks are seldom found in bends.

When the passage is not to be disputed, the straight parts of the river are the best, since the bed is less liable to vary, but a passage should not be attempted immediately below a bend, or at the confluence of a river, or at a town in possession of the enemy who might send fire-rafts, &c., to destroy the bridge. Islands may sometimes be turned to advantage.

The reconnoissance or information received from the inhabitants may lead to the discovery of *fords*. They are chiefly found in the rapid parts where a straight river widens, or obliquely across a bend. The depths should not exceed 2½ feet for artillery, 3 feet for infantry, and 4 feet for cavalry. The width of the ford is indicated by pickets, the cavalry passes up the stream, the infantry lower down.

Ice may serve for the passage of infantry when 3 inches thick, of light artillery when from 4 to 6 inches, and for any weight when above 6 inches. Even when the thickness is not sufficient, passage may be obtained by laying down straw to the depth of 6 inches, and pouring water on it; the water rapidly freezes and will carry.

(181). Before constructing a floating bridge, it is necessary to calculate the weight it has to carry, and the number of floats. The latter depends on their buoyancy, and on the scantling of the timber used for balks.

The weight to carry is that of the troops, and of the superstructure. An infantry soldier fully equipped weighs 15 stones, a horseman 18, a horse 9 cwt. 2 stones. Every man occupies 20 by 20 inches, and every horse 3½ by 9½ feet.

A 9-pounder gun and carriage with limber and ammunition weighs about 38½ cwt., and with the horses, occupies 40 feet in length. An 18-pounder ditto weighs 66½ cwt., and occupies 50 feet.

The weight of the superstructure is found by multiplying the solid content expressed in cubic feet by the specific gravity of the material, and the product by 62lbs.

The solid content of squared timber is found by multiplying the mean breadth by the mean thickness, and the product by the length: that of round timber is obtained by multiplying the length by the square of the quarter of the mean *girth*.

SPECIFIC GRAVITIES.

Iron (bar)	7·700	Larch	·530	Elm	·673
Iron (cast)	7·264	White Pine	·551	Cherry tree	·715
Tin (cast)	7·291	Cedar	·561	Oak (seasoned)	·743
Steel	7·816	Willow	·585	Teak	·750
Brass (cast)	7·824	Sycamore	·604	Maple	·752
Copper (cast)	8·788	Chestnut	·604	Plum tree	·755
Copper (sheet)	8·910	Lime tree	·604	Apple tree	·793
Lead	11·352	Pear tree	·650	Alder	·800
Cork	·240	Yellow pine	·652	Ash	·845
Poplar (common)	·383	Red pine	·657	Beech	·852
Poplar (Spanish)	·529	Walnut	·671	Olive tree	·927

The buoyancy of a float is ascertained by expressing in cubic feet the solid content of the part to be sunk, and multiplying it by 62 lbs. The product, minus the weight of the float, is the buoyancy in pounds. To find the weight which planks, trees, rafts, &c., would carry before sinking, express their solid content in cubic feet and multiply it by 62 lbs., and the product multiplied by the difference between 1 and the specific gravity of the wood, gives that weight in pounds.

For casks, the solid content is found by the formula $\cdot 01309\ L\ (D^2 + d^2 + 4\ M^2)$ in which L represents the length, D *d*, the inside diameters of the two ends and M the diameter of the middle, all expressed in inches. The product divided by 277·27 gives the capacity in gallons. The number of gallons multiplied by

10 gives the displacement in pounds, and the displacement, minus the weight of the cask is the buoyancy. The *Aide Memoire* gives a list of naval and commissariat casks:—

Puncheon . .	72 gallons	Weight, 135lbs.	Buoyancy, 694
Hogshead . .	54 ,,	,, 109lbs.	,, 576
Barrel . .	34 ,,	,, 71lbs	,, 407
Half Hogshead .	26 ,,	,, 59lbs.	,, 292
Kilderkin . .	18 ,,	,, 45lbs.	,, 194
Tierce . .	37 ,,	,, 58lbs.	,, 428
Irish barrel . .	25 ,,	,, 47lbs.	,, 275

(182). The transverse strength of beams, as given in the Handbook for Field Service, is found by the following formula.

Let $C = \frac{b\,d^2}{l}$ where $b =$ breadth, $d =$ depth, $l =$ length of given beam, all in inches.

Let S be a co-efficient, depending upon the nature of the material.

Good bar iron	$S = 6150$	Pitch pine	$= 1632$
Cast iron	$S = 7644$	Norway pine	$= 1474$
Teak wood	$S = 2462$	Riga fir	$= 1080$
Ash	$S = 2037$	Larch	from 842 to 1138
Oak	from 1081 to 2261		

If the beam is supported at one end and loaded at the other, the utmost weight it will bear $W = s\,c$.

If it is supported at one end, and the load distributed over its whole length, the weight $W = 2\,s\,c$.

If it is supported at both ends and loaded in the middle, $W = 4\,s\,c$.

If it is supported at both ends, and loaded uniformly over its whole length, $W = 8\,s\,c$

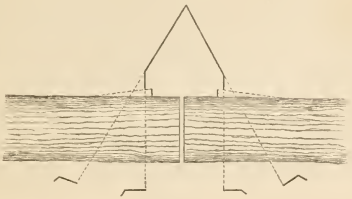
If it is supported at both ends and loaded at a distance m from one end, $W = S\,\frac{l\,b\,d^2}{m\,(l-m)}$.

In practice, the beam should not be exposed to more than half its breaking weight.

As for the strength of cordage, the same Handbook gives the following rule: the average breaking weight in cwt. of sound hawser-laid rope under 5 inches in circumference, is $4\frac{1}{2}$ times the square of the circumference in inches: above 5 inches it is 4 times the square of the circumference. Cable laid rope is not so strong as hawser laid. The weight itself of the rope is found by multiplying the length in fathoms by the square of the circumference in inches, and dividing the product by 480, the quotient gives the weight in cwt.

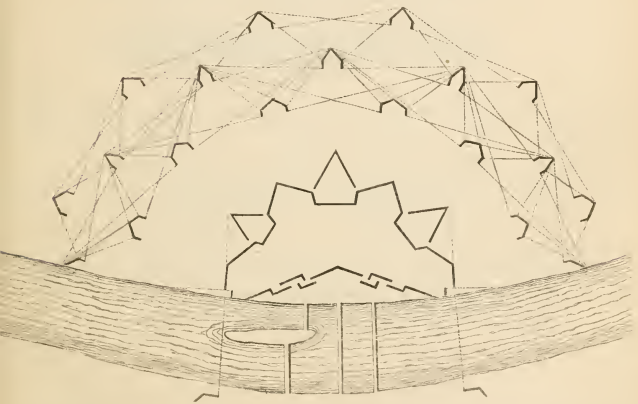
(183). When an army has constructed a bridge which is intended to stand during the campaign, either to facilitate the arrival of drafts, convoys, &c., or to secure its line of retreat, it is necessary to defend its approach by works which, according to the importance of the operations, will be either a mere redan or a

Fig. 402.



crown work, or even a system of detached works forming a retrenched camp.

Fig. 403.

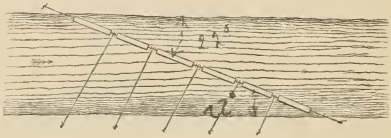


This applies also to permanent bridges, the possession of which is considered necessary. It rarely happens that more than three bridges can be constructed at

the same point: for a numerous army however, it is advisable to have two bridges for infantry and cavalry, and one for artillery and heavy waggons: this prevents confusion, one bridge serving for troops going one way, the other for those going another. Such bridges are usually 100 yards apart, and the works for their defence have necessarily a certain magnitude. Under all circumstances these tetes-de-pont should be defiladed from the neighbouring heights, and contain palisaded reduits covering the bridges, and at the same time permitting the free movement of troops, for advance or retreat. Flanking defence is obtained from batteries established on islands or the opposite bank, and the outline should be powerful enough to enable the garrison to withstand an assault. If the enemy can come on either bank, double têtes-de-pont are constructed.

(184). To prevent the enemy from destroying a bridge by sending heavy floats, fire-rafts, infernal machines, &c., down the stream, it is usual to establish a boom across the river, about 1000 yards above the bridge. It is made of trunks of

Fig. 404.



trees joined by iron rings and chains, and is inclined at an angle of 22° with the

Fig. 405.

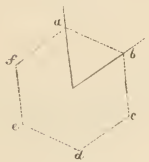
banks, so as to diminish the impulse of these floats and facilitate their removal. Posts of observation are entrusted with their guard.

CHAPTER XII.

VAUBAN'S FIRST SYSTEM.

(185). When a town is to be fortified, we suppose it to be surrounded by an

FIG. 406



imaginary figure, *a, b, c, d, e, f,* called a *Polygon.* The sides *a b, b c,* &c., are called *Fronts.*

(186). When these fronts are of the same length, and the angles of the polygon equal, the fortification is called *Regular.* When, owing to the accidents of the ground, hills, rivers, &c., these fronts and angles are not equal and equidistant, the fortification is called *Irregular.*

The study of regular fortification forms the basis of the science; it is the province of the engineer to apply it to irregular sites in the best manner, a task sometimes eminently difficult.

The fronts being supposed to be equal in length, and exposed to the same dangers, it is evident that the combinations of their defence must be alike; therefore the object of the study of Permanent Fortification is to find a perfect outline for one front—a problem still to be solved.

(187). The various lines constituting the trace or outline of a front, form what is called a *System of fortification,* and as every system results from a particular combination, it bears a particular name, usually that of its inventor.

The number of these Systems may be said to be indefinite, several hundreds

having been successively proposed, and many being still brought forward every day.

The outline of a system is independent of the length and disposition of the fronts, and to facilitate the construction, rules or formulæ are laid down for every one of them.

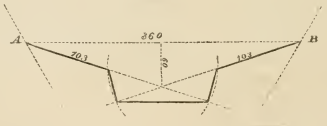
To understand thoroughly the combinations adopted for the defence, it is necessary to be familiar with the method of attack, and we shall therefore begin by giving the outline of a system (one of Vauban's, for instance), and by explaining the process of attack, before any further consideration of modern improvements.

(188). Vauban, a French general officer (1633-1707), is the author of several systems which bear his name. He never gave rules for their construction, but fortified towns as he found them, improving the fortifications already erected, and making the best of the sites. His name has become very popular, and in England he is generally considered as the inventor of the whole science. Such is not, however, the case; distinguished engineers had before him greatly improved the old outline of the clumsy bulwark, and his first system is but a slight modification of one in use before his time. (465, 275.)

He has done more against Fortification than for it; it is he who discovered the ricochet fire, and so much improved the means of attack, that the defence has ever since been unequal to it. His successors, in comparing the various fortresses he constructed, have for the sake of convenience classified them into three systems. The second system is to be found only at Beford and Landau, and the third at New Brissach. To the first belong upwards of thirty places which he entirely constructed, and many more that he merely improved. This system we shall select for example, and explain it *as required from Candidates for Military Service.** But it must be borne in mind (and this we shall see hereafter), that Vauban had no fixed system at all, and that many modifications of the following method are to be found in his fortresses; still, as the formula adopted gives all the leading features of his early methods, we select it.

The line of front A B = 360 yards.

FIG. 407.



* Before 1858 every candidate for the army was expected to draw the outline and the profile of Vauban's first system. It is for them that most of this chapter was written, and as no other knowledge of fortification was required, it was necessary to be very explicit. Hence the elementary form of this chapter.

The capitals of the two bastions are next drawn. As they bisect the angles of the polygon, the angle which they make with the line of front is equal to half the angle of the polygon. We learn from Euclid that n being the number of sides of the polygon, any angle $= \frac{(2n-4)\,90^\circ}{n}$. The capitals make therefore with the front an angle of 45° for the square, of 54 for a pentagon, of 60 for a hexagon, &c. In our example, we have selected the hexagon.

The perpendicular $= \frac{1}{6}$ of the front for the hexagon and all polygons of a greater number of sides, $\frac{1}{7}$th for the pentagon, and $\frac{1}{8}$th for the square.

The faces $= \frac{2}{3}$ths of the front.

From the angles A, B, of the polygon as centres, and with a radius $=$ the distance to the furthest shoulder angles, if arcs are described intersecting the line of defence, the chords of these arcs give the flanks, and by joining their extremities the curtain is formed.

The *main ditch* is obtained by describing from the salients as centres a circum-

Fig. 408.

ference, with a radius of 30 yards for a dry ditch, 36 for a wet one. Tangents to these arcs, drawn from the shoulder-angles, give the counterscarp.

The *Tenaille*, in the Main Ditch, coincides with the Line of Defence; its thick-

Fig. 409.

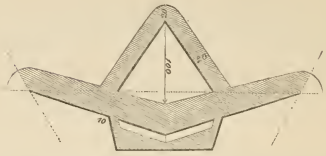
ness is 16 yards. Its extremities are parallel to the flanks of the Bastions, and 8 yards from them.

In the square and pentagon, the perpendicular being shorter and the angles less obtuse, the gorge of the tenaille thus traced would not leave sufficient room before the curtain: it is therefore necessary to draw the gorge $a\,b$ parallel to the curtain and at 6 or 7 yards from it, the escarp $c\,d$ being as usual 16 yards further.

Fig. 410

The salient of the *ravelin* is on the perpendicular at 100 yards from the re-

Fig. 411.

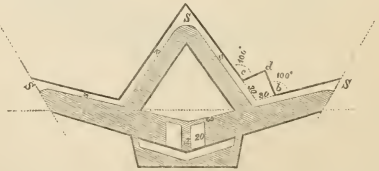


entering angle of the counterscarp. Its faces are directed to a point 10 yards from the shoulder-angle of the bastion. The ditch of the Ravelin is 20 yards wide, and its counterscarp is parallel to its faces.

In the main ditch, and between the tenaille and ravelin, a double *caponier* is usually placed; its crests are parallel to the perpendicular, and 6 yards from it; the foot of its glacis is parallel to its crests at a distance of 20 yards. A passage of 3 yards is reserved between the head of the caponier and the ravelin.

The *Covered way* is made 10 yards wide, and its crest is parallel to the counterscarp.

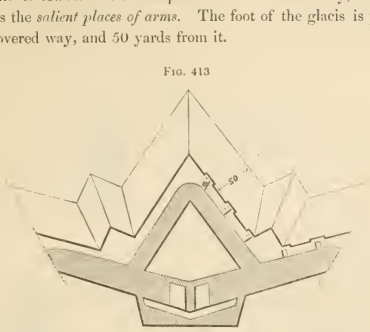
Fig. 412.



At the re-entering angles, by setting off 30 yards on each side, and drawing the faces, $d\,b$, $d\,c$, at an angle of 100° with the original tracing, the *Re-entering*

Place of Arms is found. The terreplein of the covered way, at the salients, *S*, *S*, *S*, forms the *salient places of arms*. The foot of the glacis is parallel to the crest of the covered way, and 50 yards from it.

Fig. 413



Traverses are constructed in the covered way; they are 18 feet in thickness. Those that enclose the salient places of arms are formed on the prolongation of the faces of the ravelin and bastion. At the re-entering places of arms they are perpendicular to the counterscarp. In the middle of the branches of the covered way of the ravelin there is another traverse, also perpendicular to the counterscarp. Passages called *crochets* are made around the head of every traverse: to trace them in the outline, the crest of the glacis is drawn parallel to the head of the traverse 4 yards from it, and then to the front and rear, at a distance of 5 and 8 yards respectively.

Fig. 414.

The first line of parapet that encloses the place, consisting of bastions, flanks, and curtains, constitutes what is called the *Body* of the place, or *Enceinte*. Within the glacis, works like the tenaille, caponier, ravelin, covered way, &c., are called *Outworks*. Any work erected beyond the glacis, and within musketry range, is denominated an *Advanced Work*, to distinguish it from *Detached Works*, which are beyond range, although connected with the general defence of the place.

(189). The following cuts contain the *profiles* of the various parts of this front; the line *A B* represents the level of the ground in Figures 415, 416, 417, and 418; *a b* the level of the covered way in Fig. 419, and *c d* that of the main ditch in Fig. 420.

Fig. 415.

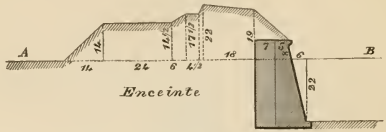


Fig. 416.

Fig. 417.

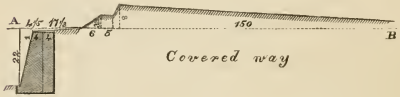


Fig. 418.

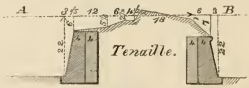


Fig. 419.

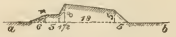


Fig. 420.

The rampart follows the outline of the crest of the bastion, having in its centre an interior space on the level of the ground,—the bastion is then called *Empty* or

Hollow. If the interior is filled up to the level of the terreplein of the rampart, the bastion is called *Full.*

A *flat bastion* is one whose demi-gorges are in the same straight line.

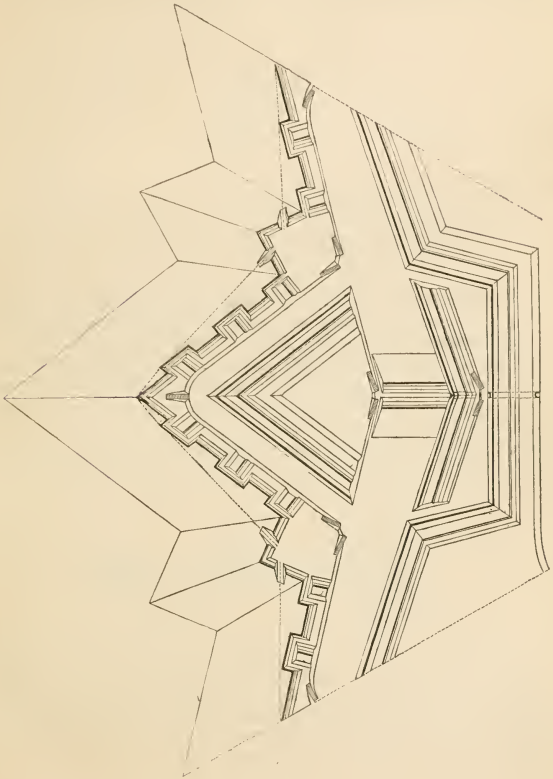


Fig. 421.

(190). Along the ramparts, ramps, from 4 to 6 yards wide and 20 to 30 yards long, are constructed to facilitate the passage of men and artillery. The figures 422, 423, 424, represent these ramps at the salient of the ravelin, on the curtain, and on the flank of a bastion.

Fig. 422.

Fig. 424.

Fig. 423.

The communication between the place and its outworks is established by means of a *postern* or gallery, under the curtain, opening at the foot of its escarp. A vaulted passage under the tenaille leads to the counterscarp of the ravelin.

Staircases called *pas de souris*, give access from the ditch to the terrepleins of the ravelin, of the tenaille, and of the re-entering and salient places of arms. They are 6 feet wide and 36 feet long, except for the tenaille, in which they are only 30 feet long.

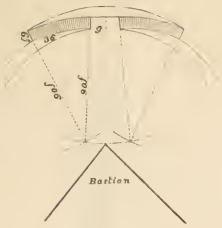
They are either single or double. Those at the salient places of arms before

Fig. 425.

Fig. 426.

the bastions are circular and described, as the figure shows, with radii of 90 and 96 feet. The centres of the ares are found by the intersection of two circles of 90 feet radii, described from the foot and the top of the staircase respectively. It is usual to leave 18 feet distance between the double staircase, measured on the foot of the counterscarp.

Fig. 427.



The covered way communicates with the country by *Sally Ports*, or cuttings, 4 yards wide and 8 yards long, made in the glacis, in the middle of every face of the re-entering place of arms. To mask them from the view of the enemy, they are directed towards the adjacent salients of the covered way. (*See* Fig. 421.) The crochets are 9 feet in the clear; the dimensions given in the outline allow for the various slopes: they are 4, 5, and 8 yards in round numbers, *exactly*, 11, 16, and 23½ feet.

The banquette of the covered way as well as that of the traverses, is provided with a row of palisades; the crochets and the sally-ports are closed with barriers. This palisading is generally dispensed with until the place is threatened with a siege.

(191). To separate wet ditches from dry ones, a wall, called a *Batardeau*, is built across; and to prevent it from serving as a passage, it forms an angle at the top, and a tower of solid masonry is erected on its middle. In these batardeaux

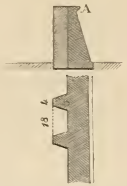
Fig. 428.

sluices are usually placed, in order to fill up the dry ditch, if necessary, when the besieger attempts to carry his approaches there. Batardeaux are generally constructed at the salients of bastions.

(192). Vauban has given to the revetments of the scarps a slope of $\frac{1}{4}$ for all heights, thereby obtaining massive walls for low scarps, and weak ones for high relief. These walls, 4 or 5 feet thick at the top, are strengthened by buttresses, or *counterforts*, on the rear, the effect of which is to relieve the wall, and to resist

the breaching batteries more effectually than a plain scarp of superior thickness (see 322), they stand from 16 to 18 feet apart.

Fig. 429.



The foundations are 3 feet deep, and their breadth exceeds by 18 inches that of the revetment. At the top of the escarp a coping-stone, A, projects, to prevent water from running along the slope and filtering through the joints. It forms a

Fig. 430.

continuous *cordon* all along the magistral line of the enceinte and of the ravelin. The wall of counterscarp is carried up to the head of each traverse.

Such is the first System of Vauban. To understand its value it is necessary to know the method of attack to which it must offer resistance, and this we shall examine in the next Chapter. Though the chief reliance is placed on musketry in the defence, it is none the less a fact that artillery is the essential element in the defence of a fortress. Bousmard calls it the soul of a place; Carnot says that a fortress is but an immense battery, &c. To the garrisoning and armament of fortresses, we shall direct our attention; of course the guns are employed chiefly on the front attacked,—some flanking the main ditch, some that of the ravelin; others on the capitals of the bastion or ravelin commanding the approaches, and on the faces of the latter a few guns flank the salients of the bastion.

CHAPTER XIII.

ATTACK OF A FORTRESS.

SECTION I.—Irregular Attacks.

Permanent Fortification, we repeat, cannot be learnt unless the attacks be thoroughly understood. We shall therefore dwell on this subject, and after having discussed the method adopted for the attack, we shall give the conduct of the defence, both being so intimately connected that any attempt to study them separately could but bring confusion.

The hostile efforts directed against a fortress are of two sorts: to the first category belong all those that are not regulated by fixed rules, to the second those that are conducted according to rules given by experience, the *ensemble* of which constitutes the art of sieges.

(193).—In the first place is the *surprise*, which is now of very rare occurrence. Its success depends on secret intelligences with persons inside the place, and on the manner in which the service is performed; it is usually combined with *attacks of Vive Force*. But the garrison must be weak, and the scarps easy of access. Secrecy and rapidity of execution are most essential, since, in case of failure, the retreat must be made under the fire of the place. Besides, the forces must be considerable, for the garrison may rally to a central point, and then charging the scattered columns of the assailants, easily overpower them. Prague, garrisoned with 2000 regular, and 3000 irregular troops, was surprised by the French in 1741. Schweidnitz, with 3000, was taken in the same manner by General Laudun in 1761. Owing to a door badly constructed, through which the French musketeers found an entrance, Valenciennes was taken in 1667. Great danger, however, attends these operations; and although the Crimean army has been found fault with for not attempting to take Sebastopol by a *coup-de-main*, yet it acted according to the rules of experience. At Cremona, in 1702, Prince Eugene contrived to enter by night with 4000 men, and to carry off the Governor, Marshal Villeroy, but an Irish regiment eventually drove him away. At Berg-op-

zoom, in 1814, the English had already surprised and occupied several bastions, yet they were repulsed with considerable loss. It is important to know the disposition of the works, the depth of the ditches, and the height of the scarps; to provide the men with ladders of proper length; to be aware of the negligences habitual in the service, &c. The attacks should never be attempted at night; the scarps of the ravelin being often mistaken for those of the enceinte, the columns lose their way, and the confusion becomes great.

Early in the morning is the best time. The columns of attack must be strong and well supported; the commanding officer should be a man of action and well acquainted with what he has to do when once in the place, or when he has to retreat. These attacks are only made now when some urgent reason, such as the arrival of hostile reinforcements, compels the general to make a desperate effort before retiring.

(194). Scaling ladders are now made in lengths of 12 feet, and tapering so as to fit into one another. They weigh 50 pounds each. Their extremities are provided with staples for fixing them together, and they are secured by lashings.

Fig. 431.

Each joint, when thus fixed, gives an effective length of 10 feet. Smaller ladders, 7 feet 6 inches long, are also made, and in order to employ them simultaneously with the others, they have the same width at top and bottom.

A wall from 10 to 18 feet high, requires 2 lengths; from 18 to 28, three; from 28 to 35, four. As a rule, the ladder should over-reach the height of scarp 3 feet, so that it may be placed one yard from the foot of the wall, and also assist the men in stepping from it upon the wall. Two men carry one length, and three men a double length.

When a fortress is to be escaladed, a previous reconnoissance will ascertain the heights of the scarps.

The men intended for the operation are divided into two equal portions, the storming party and the covering party.

The ladders are prepared in lengths and double lengths, and laid on the ground out of sight of the enemy. The storming party divided into sections of five proceed to the ladders, three men taking the double, two men the single

lengths. They move on, carrying the ladders on their right shoulder, and having their muskets slung over the left. They are guided by engineers, and accompanied by sappers; the covering party lies flat on the crest of the glacis, ready to fire at the parapet should the defenders attempt to prevent the escalade. The ladders are applied to the counterscarp, and when the storming party is in the ditch, it proceeds to the escarp with $\frac{2}{3}$ only of the ladders; those left at the counterscarp will enable the covering party to come to their support. The ladders are planted firmly; but if they are found too short, they are raised, and an additional length is secured below. The men then fix bayonet and ascend. It is proper to give a sap-hook to each leading man, to enable him to secure a good footing, and give assistance to those that follow.

A new kind of scaling ladder has been lately proposed by Mr. Fawcus. It is only 6 feet long, and weighs 25 pounds. The lashing is done away with, and the lengths are secured by bolts.

(195). Another sort of attack, which has been called *Artillery attack*, may succeed when the escarps are low and exposed. It consists in opening a breach at 600 yards distance, or even further if necessary. Approaches (206) are then rapidly executed up to the ditch, without giving time to the defenders to throw up intrenchments, and a constant fire of mortars and howitzers is kept up on the breach until the moment of attack. In a day or two the breach can be made. Ciudad Rodrigo, and Badajos, were breached in this manner.

(196). *Bombardment* has generally but little effect, since both the men and ammunition in a garrison are usually provided with bomb-proof shelters; the strength of the fortress is not much impaired, the houses alone suffering.

With populous towns, little disposed to resist, it may answer; but if the garrison is determined, shelter will soon be constructed and fires extinguished. These attacks are of difficult execution, and require enormous power of transport.

(197). *Blockades* are resorted to against a garrison abundant in men, but badly provisioned—which happens more frequently than is generally supposed. In 1806, after the battle of Jena, the French found large bodies of Prussian troops heaped, so to speak, in fortresses. In that case it is essentially necessary to blockade exactly all the circumference, and to occupy vigorously all the strong points, in order to suppress any attempt on the part of the enemy to evacuate.

(198). *Siege.*—Regular attacks proceed more slowly, but are more certain; to take up a position round the place, intercept all communication with the exterior, approach nearer and nearer to the crest of the glacis, open a breach in the enceinte, reach the garrison, and compel it to surrender,—such is their ensemble.

These attacks once begun must be carried on without interruption, otherwise the garrison will construct new intrenchments, replace its parapets, and organize

a more powerful defence; they should therefore only be undertaken when there is a certainty of the arrival of tools, artillery, ammunition, &c.

This question of tools and implements is very important, and although their quantity varies with the strength of the place and that of its garrison, yet an idea may be formed by observing that the most recent sieges give, as necessary, an average of 7000 pickaxes, 10,000 shovels, 3000 axes, 5000 hatchets, besides special tools for sappers and miners. The implements required are 7000 fascines for trenches, 100,000 ditto for revetments, 20,000 gabions, 10,000 fagots for sapping, 50,000 * sandbags, besides a proportional number of pickets, hurdles, sap rollers, blinds, &c.

SECTION II.—Siege.

Section A.—

(199). The first operation made by a besieging army is the *Investment* of the place.

Its object is to cut off all communication with adjoining towns or corps of troops, to prevent the garrison from getting rid of encumbrances, to lay hands upon all neighbouring and distant resources, such as corn, cattle, wood, &c., to intercept any detachment not actually in the place, and to favour the reconnoitring—an important item, which will spare false movements and loss of time. To insure success, the investment should be sudden. It is generally carried out by detachments of cavalry and field-artillery, or of light infantry, according to the nature of the ground, which during the day keep themselves out of range, and approach nearer at night. Their strength varies with local circumstances, and their march is regulated so as to bring them at the same time before the place.

The investment should be complete, otherwise the besieged will be enabled to receive reinforcements, as was done at the siege of Namur in 1695, at the attack of Flushing (1809), or to cause serious annoyance, to the besiegers, as at Badajos in 1812.

The army follows one or two days after. In the mean time, the position of the camps has been determined by reconnoitring; they are usually out of range (three thousand yards from the glacis), and the best use is made of the ground to conceal them from the views of the place. Sometimes barracks are constructed. The parks of artillery destined to receive the ordnance stores and ammunition,

* At the siege of Gerona (1809), by the French, one battery of 6 pounders alone required 80,000 sandbags.

At Constantine, in 1837, the number of sandbags employed in the construction of the batteries was enormous.

and the engineers' park for the tools and implements, &c., are formed at the same distance.

Whilst the troops are encamping, field-works are thrown up to occupy the chief points and protect the parks and magazines of all sorts against surprise; and such bridges, trenches, &c., as are necessary to connect the investment, are constructed. In early times it was customary for the besieger to intrench himself between lines of contravallation and circumvallation, the former to resist the sorties, the latter to protect the rear against any attempt made to force him to raise the siege. This method is now obsolete. The lines of contravallation are to a certain extent replaced by the trenches themselves, and a few redoubts on the flanks. As for the lines of circumvallation, experience has proved that they are dangerous (81) as defensive positions, unless the enemy can present himself on a limited front only. It is better, in case of an attack on the rear, to leave sufficient forces to guard the trenches, and to march to the enemy.

(200). In the meanwhile, officers proceed to make accurate *reconnaissance* of the place, in order to determine the *point of attack*. During the day, they advance with a small escort to within 400 or 500 yards of the glacis. At night they endeavour to reach the covered way, fathom the depth of the ditches, &c.

The reconnaissance should be made so as to leave the enemy in perfect ignorance as to which front it is intended to attack, otherwise he will lose no time in strengthening it, by all the means he can dispose of; and to deceive him, false attacks have sometimes been made, as at the siege of Quesnoy in 1794.

The *general plan* of the place, and of the surrounding country, is kept by the engineers, who sketch every day on it the works destined to be constructed during the following day, and definitively trace the works executed the day before. It is usually made at the scale of $\frac{1}{10000}$; the plan of the attacks as far as second parallel is on a scale $\frac{2}{10000}$, and that of the rest on a scale $\frac{4}{10000}$. Plans of most fortresses are always to be had: the reconnoitring party then completes the information.

In the selection of the point of attack, the nature of the soil has a great influence, a rocky soil being an insurmountable obstacle. Marshy and gravelly soils are to be avoided, as well as those which are liable to be inundated. A river is also a serious obstacle.

The configuration of the ground is next considered. When it rises towards the place, it facilitates the defilade, but is very disadvantageous for the batteries; hollows running perpendicular to the front are dangerous, but a ridge affords good support to the trenches, and may eventually mask them.

It is important to direct the attacks upon points where a superiority of fire can be obtained; therefore re-entering angles and straight lines are left, and salients are selected. These are examined, as well as the works that support them; their

flank defences, the height of their escarps, their dry or wet ditches, the number of outworks to be successively carried, the facilities for the besieger to throw up intrenchments on these points, &c. The proximity of woods, the facility of communication, the line of retreat, &c., all influence the selection of the point of attack.

The point of attack being selected, the commanding officer of engineers, assisted by the officer commanding the artillery, draws the project of attack; and the commander of the forces decides, in case any difference of opinion should arise.

This project generally embraces one front only, and consists of three partial attacks, one on the ravelin, and one on each bastion. Attacks on two fronts require a very large force, and if the two fronts are not contiguous, they demand a double army.

When the angle of the polygon is very obtuse, it is better to attack two ravelins

Fig. 432.

and a bastion, otherwise the collateral ravelins AA would become a serious impediment, their fire taking the besiegers in flank.

If the angle of the polygon is not very obtuse, it is better to select two bastions

Fig. 433.

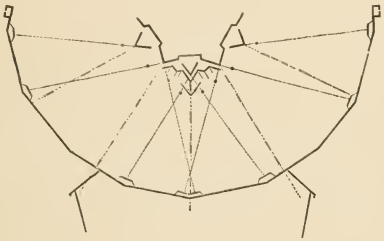
and their ravelin; the collateral works give but an oblique defence, and the besieger has the advantage of giving two simultaneous assaults on the body of the place.

(201). During the investment and the reconnaissance the tools and implements are collected and prepared, if this has not been done before, and according to the estimates of the engineers, the necessary number of gabions, fascines, sap faggots, sap rollers, pickets, &c., are made.

	Length.		Diameter.		Weight.	Time for execution.
	ft.	in.	ft.	in.		
Fascines, small	6	0	0	7	33 lbs.	Three men in 20′.
Fascines, large	18	0	0	9	2 cwt.	Four men in 2 hours.
Tracing pickets	1½	0	0	1	.....	One man makes 25 in one hour.
Revetment pickets	3½ to 4 ft.		0	1½	.....	Ditto
Gads	5	0	0	½	.....	One man makes 50 in one hour.
Gabions for sap	2	9	2	0	40lb. to 50	Two men make one in 20′.
Gabions	3	0	2	0	60lb. to 70	Ditto
Sap faggots	3	0	0	9	30lb.	One large faseine sawn into 6.
Sap rollers.. outside gabion.	6	0	4	0	6 cwt. to 7	Three men in 17 hours make 1.
Sap rollers.. inside gabion ..	6	0	2	6		
Sand bags.. empty	2	8	1	4	11lb. 2oz.	One man sews one in 40′.
Sand bags.. full	...		...		60lb.	

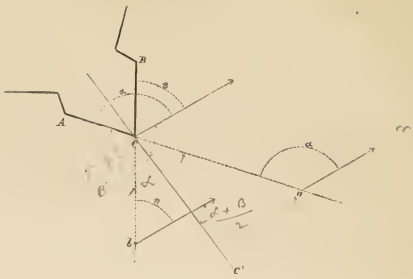
(202). It is also of the utmost importance that the prolongation of the faces of the works of the front of attack should be accurately determined; and the position of the capitals ascertained, and marked by pickets, on the ground. This is some-

Fig. 434.



what difficult, because the glacis now marks the masonry, but in watching the green slopes in the morning and in the afternoon, the various shades of light they present serve to guide the officer in his reconnoissance; he must occasionally ascend a small ladder, when the sun does not shine. If the slopes are clearly seen, the prolongation of the capitals is at once obtained by planting two pickets in a line with the intersection of the parapets at the salient angle, and the intersection of the crests of the glacis. If this is not possible, the prismatic compass will answer the purpose (fig. 435): measure the bearing α of a A, and then β of b B, then $\frac{\alpha - \beta}{2}$ gives the angle of the salient, and $\frac{\alpha + \beta}{2}$ the azimuth of the

Fig. 435.



capital; after this, aim at the salient, and move about until the compass bears $\frac{\alpha + \beta}{2}$, when a point of the capital will be found.

Section b.

(203). *First Parallel.*—Let us suppose that the attack is made on a ravelin and two bastions. The first step is to throw up a continuous intrenchment that will serve as a basis to the subsequent operations. It is parallel to the general contour of the fortress: hence its name of "parallel." It is constructed at 600 yards from the most advanced salient of the place, because at that distance the troops employed to break the ground are not much exposed to grapeshot; the garrison cannot hear the noise, and is too far off to attempt a sortie; besides, experience shows that, at this distance, three-fifths of the rounds fired from the batteries established before the parallel take effect. At a greater distance than 600 yards the practice would become too uncertain. Sometimes an accident of the ground permits the parallel to be established at a smaller distance.

In 1794, at the siege of Maestricht, a hollow within a small distance of the place served to establish the extremity of the parallel. At Bouchain, a hollow within twice pistol range allowed the besiegers to construct a place of arms the first night of the opening of the trenches. At Limburg, the dragoons succeeded in forming a lodgment within pistol range, under cover of some hedges. At Bayonne, in 1814, a hollow road parallel to the works enabled Wellington to come within 240 yards of the place. At Malta, in 1800, fences of stone were similarly turned to account by the besiegers.

At Tortosa, in 1810, Marschal Suchet opened the trenches at 300 yards, being

favoured by a heavy fall of snow. At Antwerp, in 1832, the French opened theirs at 400 yards, being covered by hedges and garden enclosures.

It is sometimes necessary to construct the first parallel at a much greater distance than 600 yards, when the nature of the ground renders the construction of the approaches (206) difficult. At the siege of Ypres, Friburg, Mons. Namur, Maestricht, Gibraltar, &c., the ricochet batteries could only be opened at a distance from 1000 to 1200 yards.

The *tracing* of the parallels, due to Vauban, who employed them for the first time at the siege of Maestricht, in 1673, is very important. The parallels must embrace all the works that command a view of the attacks, generally the collateral fronts. They enable the besieger, with immense advantage, to repel the sorties, to flank his further advance, to protect his batteries, and to connect all the attacks.

The first parallel is traced on the ground by means of pickets, close enough to guide the engineers during the night, and this is usually done at dusk, a short time before the working party begins, pieces of tape connecting the pickets to prevent mistakes.

Between the first parallel and the parks, at 1200 or 1500 yards from the place or wherever convenient, *depôts*, or stations, for the tools and material necessary for the daily supply of the trenches, are established, and their communications with the parallel are traced at the same time.

When these tracings are completed, the number of men necessary for the excavation is easily calculated, each man being allowed 6 feet.

(204). At night-fall these workmen are collected in the depôts, where they receive a shovel and a pick-axe each, and are formed into as many columns as there are capitals crossing the parallels. It is important to deceive the garrison as to the time fixed for the "*opening of the trenches*," therefore it is only at night that each detachment, about 25 strong, commanded by its officers and guided by engineers, marches to the tracing of the parallel, filing off right and left as they arrive there, and lying flat on the ground; the engineers ascertain that the men follow exactly the outline, and place themselves 6 feet apart, and to make this sure, each man is sometimes made to carry, as in the French service, a tracing fascine, which he places in a line along the tracing. At a signal, the whole working party begins to excavate, throwing the earth in front to obtain immediate cover.

These workmen are protected by a guard, calculated at three-fourths of the garrison: the cavalry are at the extremities of the parallel ready to charge; the infantry takes up a position in front or in rear of the parallel: the different battalions detach pickets in front, and these again send vedettes and frequent patrols. The covering party should avoid firing on small sorties, but repel them with the bayonet, and retire into the parallel when it is sufficiently forward to afford cover.

During the first night the parallel is excavated 5 feet wide and 3 feet deep, and the communications with the depots are also executed with the same profile.

Fig 436.

Next day, both workmen and guard are relieved, and the trench is widened to 10 feet, slanting in the rear to carry off the water and defilade the space, the guard taking position in the parallel itself.

Fig. 437.

In general, working parties are relieved every twelve hours, at dusk and at daybreak, the works being begun at night.

To enable the guard of the trenches to fire over the parapet, two steps, supported by fascines, are constructed in the space between the capitals, and in some

Fig. 438.

part of the parallel similar steps are cut on both sides of the parapet, to permit

Fig. 439.

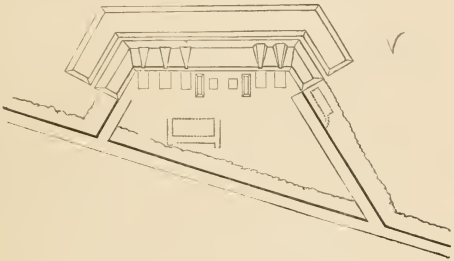
the troops to clear the parallel easily, in order to march against the sorties of the besieged.

The profile of the parapet of the trenches is not sufficiently strong to resist artillery, but the defenders will not waste their ammunition in attempting to destroy it. The chief protection afforded by the parallel is concealment from the enemy's view, the troops being scattered behind an extensive line, it would hardly be worth while for the garrison to fire at them at random. The extremities of the parallel are usually secured against flank attacks by redoubts.

(205). *Batteries.* On the second night, when the first parallel is completed, the besieger constructs his batteries to subdue the fire of the defence, and to permit further advance upon the place. They are constructed in front of the parallel (at a distance varying from 30 to 50 yards) and rarely in the parallel itself, because they would obstruct the movements of troops, and more rarely still in rear of it, because the fire might inconvenience the men in the trenches. But this depends much upon the locality.

The *ricochet batteries* are established perpendicularly to the prolongation of the faces which are to be enfiladed. They may receive from 3 to 6 guns to ricochet

Fig. 440.

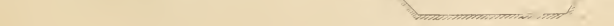


the terreplein of rampart of the ravelin or bastions, and 2 howitzers to ricochet the covered way. The space between the prolongation of the parapets and ditches affords in these batteries room for a few mortars.

Those batteries which are intended to silence the works which cannot be enfiladed, are placed directly opposite them or wherever convenient: they are called *counter batteries.*

All these batteries are distinguished according to their nature, as: *Cavalier batteries,* when the platforms of the guns are above the ground; these are only employed when the inequalities of the ground would intercept the shots.

Fig. 441.



Elevated batteries, when the platform is on the ground. This is the sort most generally employed, especially for counter-batteries; and the only kind which can be constructed when the ground is marshy.

Fig. 442.

Sunken batteries, where the level of the platform is 3 feet below ground, the soles of the embrasures coinciding with its surface. These are objected to because the necessity of excavating the whole terreplein, 30 feet more or less, entails much

Fig. 443.

labour; the terreplein, sunk at first 3 feet to get cover, must afterwards be filled 6 inches; no platform, no revetment, &c. can be fixed until the excavation is completed; the embrasures cut through the parapet are invariably badly made; the foundation for the platform is often too uneven, and the magazines being on the ground are not so well covered. It is only when a parallel is transformed into a battery that this kind is advantageous, since part of the work is already done, or when the ground falls to the rear. Should the ground rise to the rear the terreplein must be sunk, but the labour is much increased.

Half-sunken batteries are preferable, especially for ricochet, because the guns

Fig. 444.

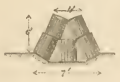
require no elevation, and there is no danger of seeing the shots intercepted by rising ground, whilst they require much less time for their construction.

In common soil and under ordinary circumstances, the elevated batteries should be completed in 36 hours, the half-sunken in 24 hours; but all of them should be finished before they open fire simultaneously, because if they were to open their fire in succession the enemy might destroy them in concentrating his fire on each.

The parapet of these batteries is made 18 feet thick, and an *epaulment* is thrown up at each extremity to cover the gunners from the oblique fire of the collateral

works; it is usually 12 feet thick. Splinter-proof *traverses* 6 feet thick at the bottom, and 6 or 7 feet high, and 16 feet long, are erected between each 2 or 3 guns; they are perpendicular to the parapet, and about 2 feet from it, thus leaving

FIG. 445.



a passage for the men to make their escape from that part of the battery in which a shell falls.

To order the working party destined to construct a battery, we suppose the work to be divided into as many portions as there are guns, reckoning an epaulment as a portion, and the parapet before each traverse as half a portion. From 9 to 13 men are allotted to a portion. The platforms for guns, 9 feet wide by 15 feet, have a rise of half an inch to the foot, to diminish the recoil: mortar platforms hitherto 8 feet square, and now 9 feet wide by 7 feet 6 inches, are laid horizontal. Four men can lay a platform in one hour.

Mortars require no embrasure; they are placed 15 or 18 feet apart, and removed to a distance of 12 feet from the epaulment when fired at 40° elevation. This distance must be increased when the angle of elevation is less. The superior slope of the parapet generally counterslopes.

The batteries are armed at night, the guns being taken across the country, since the bottom of the trenches would be too soft. Fifty men can drag a 24-pounder.

Powder magazines are placed either in the epaulments or 30 yards in rear of the batteries. The *expense* magazine holds sufficient ammunition for 24 hours' firing, and feeds 3 or 4 pieces. A laboratory magazine serves for the whole battery the purpose of loading the shells, weighing their charge, and fixing the fuzes. The form of these magazines varies (figs. 446, 447). We represent here the form which is most recommended. Fig. 448 is a section of a magazine in the epaulment.

FIG. 446.

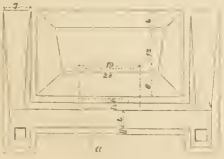
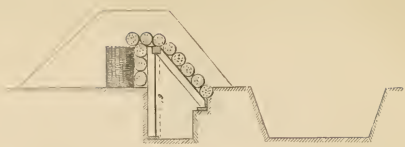


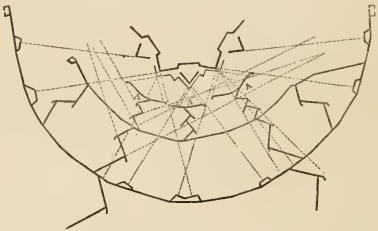
FIG. 447.

Fig. 448.



(206). When the batteries are constructed, the besieger in order to advance towards the place, executes covered roads or trenches in the shape of zig-zags, called *approaches*, *zig-zags*, or *boyaux*. They are not directed in a straight line towards the place, because they would be enfiladed, but proceed obliquely. They follow the capitals, crossing them alternately right and left, because it is the shortest direction they can follow, and also because they do not obstruct the fire of the ricochet batteries; they are besides less exposed in the undefended sector. These zig-zags are very nearly limited in length by two lines intersecting the first parallel, at about 70 yards from the capitals and converging on the salient at-

Fig. 449.



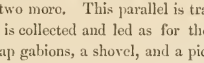
tacked; the labour is thereby limited to what is strictly necessary; and the changes of direction, an operation more or less long and dangerous, are rendered less frequent. The prolongations of these zig-zags should always fall clear of the most advanced salients of the collateral fronts, at 20 or 25 yards from them, as Vauban recommended. A return of 30 feet is made at every extremity to cover the approach in rear from the enfilade fire which the enemy may dispose of in sorties, and also to allow room for tools, &c. They should not form with one another an angle less than 30°. They may be made 1 foot less wide than the parallel, and 6 inches deeper, because more cover is required on account of their obliquity.

SECTION C.

(207). *Second parallel.* On the fourth night the approaches have reached half way between the fortress and the first parallel, and a second parallel is constructed, but if the batteries have not slackened the fire of the defence, it is necessary to wait a night or two more. This parallel is traced by the engineers, and at dusk the working party is collected and led as for the opening of the trenches, every man carrying two sap gabions, a shovel, and a pick axe.

Arrived on the spot, they place their two gabions 2 feet beyond the tracing, and lie flat on the ground till the signal is given for the excavation to begin on all the line. The gabions are filled up in 15 minutes, and afford a musket-proof shelter. This process is called the *Flying Sap*. The first night the excavation is made 5 feet wide and 3 feet deep, each man completing his 4 feet, and leaving a berm of $1\frac{1}{2}$ feet.

FIG 450.



A covering force in the approaches, or in front if the ground permits it, protects the workmen. Next day the work is completed as for the first parallel, and

FIG. 451.

the gabions are crowned with one or two rows of fascines. Banquettes are also erected for the guard of the trenches, and steps cut to pass over.

This parallel protects the working parties in their further approaches, and without it they would be nearer to the enemy than to their own supports.

As is seen by these profiles, the second parallel has a greater solidity, being provided with a revetment, to resist the projectiles.

This parallel is protected in flank by redoubts, or is connected to the first by zig-zags.

When the ground masks some of the batteries of the first parallel, or when, owing to the obliquity of the faces of the bastions, these batteries are too far to produce effect, they are constructed afresh on the corresponding points of the second parallel. This is done in two ways, either the parallel itself is transformed into a battery, in which case trenches are excavated some 20 yards in the rear to keep up the communication, or the batteries are constructed in front of the parallel. In this case, which occurs when the line of fire is rather oblique, a flying sap is carried out to the point, where the counterscarp of the epaulment is

intended to be, then it turns round following the counterscarp of the parapet. This flying sap serves as a screen, behind which the men construct the battery. At night the guns are dragged across the country.

(208). *Demi-Parallels.*—From the second parallel the besieger advances again in zig-zags, till he arrives within 150 yards of the crest of the glacis, where his proximity renders the sorties more serious; then he is obliged to excavate *Demi-Parallels* or *Places of Arms*, or portions of parallels destined to contain a strong guard, to protect the workmen and quell the musketry of the place, A, A, A. (Fig. 449.)

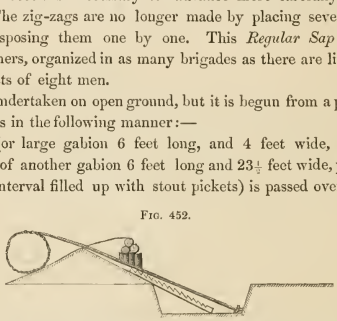
These places of arms, from 100 to 150 yards in length, extend right and left as far as the prolongation of the covered way of the ravelin, or the re-entering places of arms; they are widened at their extremities to receive light mortars or howitzer batteries, which throw stones or shells along the covered way, to keep down the musketry fire; the further progress of the attack depending greatly upon the result of this.

(209). After the second parallel, the flying sap can seldom be resorted to, because the musketry of the defence begins to tell, and grapeshot to harass the approaches. It becomes necessary to advance more carefully, and therefore more slowly. The zig-zags are no longer made by placing several gabions at a time, but by disposing them one by one. This *Regular Sap* is entrusted to Sappers and Miners, organized in as many brigades as there are lines of approach. A brigade consists of eight men.

It cannot be undertaken on open ground, but it is begun from a parallel or a zig-zag, and proceeds in the following manner:—

A sap roller (or large gabion 6 feet long, and 4 feet wide, rendered bullet proof by means of another gabion 6 feet long and 23½ feet wide, placed inside the first, with the interval filled up with stout pickets) is passed over the parapet of

Fig. 452.



the parallel by means of two spars and ropes, and an opening is made into this parapet by removing two gabions.

Sapper No. 1 places a gabion behind the end exposed to fire, and to make room for it pushes the sap roller by means of two *sap forks*, or long poles. Provided with hooks, he then excavates a trench 18 inches wide, and 18 deep, leaving a berm of 1 foot, and with the earth fills the gabion.

Another gabion is placed beyond the first in the same manner, and a sap faggot,

or two sand bags, are placed opposite the parts where the gabions are in contact to protect that weak part from musketry. The sapper continues in this manner, working on his knees, carefully avoiding to expose his body to view, until he has excavated 5 feet in length, and placed 3 gabions.

FIG 453.

FIG. 454.

FIG. 455.

Sapper No 2, also on his knees, works behind the first, and widens his trench 20 inches. Sapper No. 3 follows the second, and deepens the excavation by 18 inches. The fourth Sapper widens the whole 10 inches to the depth of the third.

The work proceeds, the earth being thrown over the gabions, and two or three rows of fascines are placed on the top of these gabions to increase the height of the parapet. When the first sapper has filled two gabions and placed a third, they change places, the first taking the rear, and the other replacing the one in front. The other four sappers of the brigade hand up materials to the working half, and every hour the half brigades relieve each other.

Under ordinary circumstances a sap advances at the rate of 8 or 10 feet per hour. The sap is afterwards transformed into an ordinary trench by the working parties.

(210). Another method, less irksome but not quite so rapid, is also employed; it is called the *standing sap*. The squad consists of three men. No. 1 leaves a berm of 18 inches, and digs a trench 18 inches wide and 3 feet deep. After

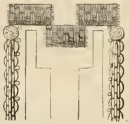
FIG. 456.

having filled two gabions and loosened earth for a third, he goes to the rear; No. 2 widens his trench 18 inches, and No. 3 widens No. 2's work 18 inches.

(211). If the approaches cannot any longer be made by zig-zags, (*i. e.*, when 32 yards in advance cannot be gained by 100 yards of zig-zags), the besiegers must advance in straight line, which is done by means of a *double sap*.

It consists of two single saps working side by side, so as to form a trench 10 feet wide at bottom, or only 6 feet, when there is no necessity for bringing

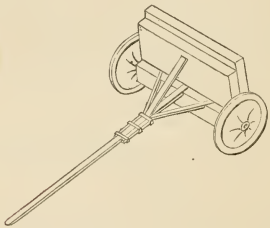
Fig. 457.



guns through it. Each head of sap is covered by its sap roller, the interval between the two being protected by a third sap roller placed in rear of them.

Instead of a sap roller, a mantlet, bullet-proof, carried on small wheels, is sometimes used, and in future sieges it will be necessary to adopt this method to cover the head of the sap.

Fig. 458



This sap cannot be carried forward beyond a short distance, because it would be enfiladed by the defenders, who are enabled to see into it by the command of the place. In order to obviate this, returns are made by single sap at right angles to the double sap, so as to leave traverses at greater or less intervals, according to the requirements of defilade. This sap, in ordinary circumstances, proceeds at the rate of 30 yards in twenty-four hours.

Fig. 459.

Fig. 460.

The necessity of avoiding enfilade has caused the adoption of a *serpentine* sap (fig. 461), but the frequent turns occasion delays, and therefore this sap is not recommended.

Fig. 461.

Fig. 462.

(212). Another sort of sap, due to Colonel Jebb, R. E., and called *direct double* sap (fig. 462), is now superseding the old methods, because it proceeds at a greater rate—40 yards in twenty-four hours. The gabions of the right and left sap are placed 26 feet apart, the head of the whole space being covered by four or five sap rollers lashed together. A third squad works on between, placing its gabions as a third row in the centre, so as to give 12 feet clear on either side. At every interval of 12 feet or more, according to the requirements of defilade, this third squad makes a short sap alternately across, in order to construct a traverse. Other squads follow these to complete the work; and the central row of gabions being removed, the two trenches of the right and left sap are united, forming a winding trench, with lock traverses. Besides the saving of time, this sap possesses the advantage of always going ahead, and of avoiding the difficulties of turning.

(213). When the vertical fire of the defenders renders the passage of the saps dangerous, they are protected by dispositions similar to those represented. (Fig. 463, 464).

Fig. 463.

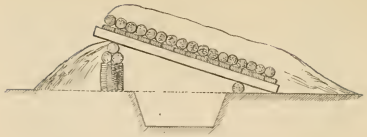
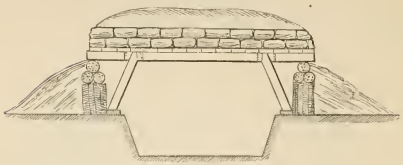


Fig. 464.



Section d.

(214.) When the heads of the saps reach the foot of the glacis, they break into single saps on the right and left of each capital, to connect their work together, and form the *third parallel.* This happens the ninth or tenth night. This parallel connects the heads of the attack, and gives to the besieger a secure position to collect materials, and prepare for further operations. As it does not extend on either flank much beyond the salients attacked, it is much shorter than the others; but it is wider, usually, 24 feet, in order to receive a strong covering party, whose assistance may be in constant requisition, and to hold the great

Fig. 465.

quantity of materials which is constantly wanted in the further advance. The parapet must therefore be higher, and this is done by placing two rows of large fascines over the gabions. Some loopholes, formed with sand-bags, enable the besieger to keep up a brisk musketry fire.

Batteries of mortars and howitzers are also constructed when necessary, to

silence the fire of the covered way, and are usually placed on the capitals of the re-entering places of arms. During this period of the siege, $\frac{2}{3}$ the guard of the trenches is placed in the third parallel, and $\frac{1}{3}$ in the second.

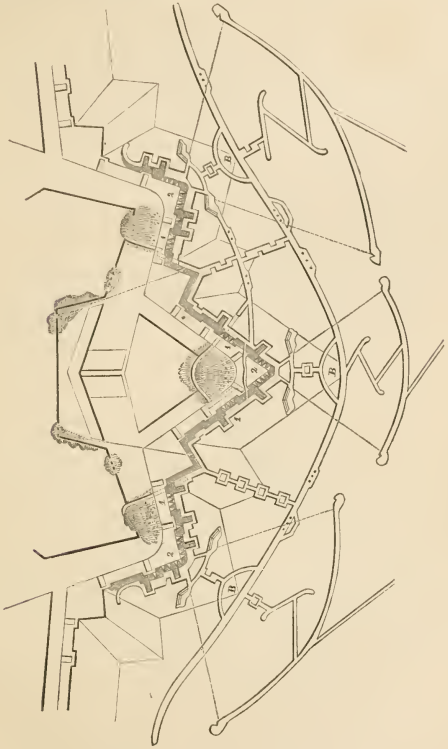


Fig. 466.

The besieger now approaches the momentous period of the siege. To enter

the place he must destroy or breach the escarp of the ravelin, and do the same (217) to the body of the place before giving the assault. His batteries must be established in the parapet of the covered way, and to render their construction less dangerous, trenches are excavated to sink them. This sap is called the *Crowning of the Covered Way.* It is made either by regular or by flying sap.

(215). When the covered way must be carried by open force (an operation only to be attempted in cases of great necessity, on account of its danger), the requisite gabions, fascines and sandbags are collected in the third parallel. Besides the usual guard of the trenches, and the workmen, 400 or 500 men per salient, are disposed on their rear. The batteries open a brisk fire, and when they cease, suddenly, at a given signal, the men, clearing the parallels, rush to the covered way, destroy the palisades, and engage the defenders; as, in the meanwhile, the place ceases firing to avoid injuring their own troops, the sappers dispose their gabions according to the direction of the engineers, at six yards from the crest, and begin the crowning, whilst others establish the communications with the parallel by means of a flying sap.

This method is only resorted to when the garrison is not numerous.

This crowning is very dangerous: it must be well preconcerted, to avoid confusion; yet the great accumulation of men on the same point may prove fatal if the enemy can bring a gun to bear upon it.

There is no doubt that the attack of the covered way is, after the assault, the most dangerous and difficult operation of a siege. Vauban pronounced himself very strongly against an attack of *vive* force:—

"Of all the obstacles which the necessity of defence has invented to resist the attacks of the besieger, I know of none which has cost more trouble to surmount than the counterscarp, when it is defended; for the first attempt, whether successful or unsuccessful, but more especially in the latter case, which is also of more common occurrence, is never made without great losses. I recollect that at Stenay, five successive attempts, which were attended with a loss of 500 men killed or wounded, were failures. There were three failures at Valenciennes, and yet the besiegers were not masters of the counterscarp when the siege was raised. The attack of the Marquis of Uxelles at Montmedy in 1657, resulted in nothing; and in that of Marshal de la Ferté, from the first lodgment, which failed three times, to the last, which was as often unsuccessful, there was an interval of three months. I have heard it said that there were three failures at Dunkirk, and that at the last siege of Arras there were even as many as six or seven failures, in each case attended with great losses. Indeed, in sieges of places which make but a feeble defence, there are invariably three times as many men lost before the taking of the counterscarp as after; and this always arises through a too great eagerness to hasten the operations, an eagerness so great that not half the

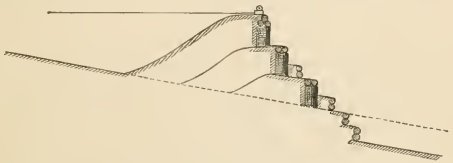
necessary precautions for such a contest are overtaken, which, instead of advancing the operations one day, very often retards them two, and that too at the expense of the best troops, who, on such occasions, meet with a wretched fate."

To this it may be added that—in 1676, at Philipsburg, it cost the besiegers 1200 men; in 1695, at Namur, 3000 men; in 1702, at Kaiserwerth, 2500 men; in 1708, at Lille, 6000 men; in 1713, at Friburg, 1750 men.

(216). When the attack on the covered way must be made systematically, the besieger advances from the third parallel in double sap, but when possible he avails himself of the slope of the glacis by opening two saps from the parallel, at about from 30 to 40 yards on each side of the capital; and excavating in a circular way, so as to make the saps meet on the capital at about from 30 to 20 yards in front, he forms what is called the *circular portions* B, B, B. They are not exposed to enfilade like the saps.

From the circular portions, the besieger advances by double sap to within 30 yards of the covered way, a little beyond the range of the grenades of the defenders. The two brigades part then and advance to the right and left along the sides of the glacis describing the head of a T, and push on to about 20 yards beyond the prolongation of the crest of the covered way. The outer ends of these saps are transformed into *Trench cavaliers*, or high parapets formed of 3 or 4 tiers of gabions. They were employed for the first time by Vauban, at the siege of Luxemburg, in 1684.

FIG. 467.



They consist of two faces each about 10 yards long, inclined at from 100° to 120°, (fig. 467, 474,) the first commands the terreplein of the covered way; the second, serves as a mask against enfilade and reverse fire, to look upon the places of arms of the bastions. The relief of these cavaliers must be such, that the shot may strike the foot of the first traverse and plunge along the other parts of the covered way. Marksmen posted on their sides compel the besieged to give up this outwork. Then two squads of sappers, issuing from the extremities of the T, advance in double sap to the salients, and join at six yards from them; there they part again, to follow the crest on both sides at that same distance of six yards,

and the crowning proceeds. At the siege of Antwerp (1832), the French did not construct any cavaliers, but employed instead batteries of howitzers and mortars, a plan which it is necessary to adopt whenever the artillery of the garrison is not almost entirely silenced.

(217). We have already seen that in polygons of many sides, the ravelins prevent the besiegers from advancing on the bastions, and that it is necessary to carry two ravelins before assaulting a bastion. This case we have not selected because we shall have an opportunity of explaining the process of attack against a modern fortress in which the ravelins have a great saliency. We suppose that the bastions and the ravelin can be assailed simultaneously, and we therefore represent in the diagram the works of the besieger against the ravelin as well as against the bastion, although in reality the assault of the ravelin may not take place, the enemy abandoning this outwork when the bastions are breached.

(218). We are supposing the Trench cavaliers to have been completed on the 12th or 13th night, and the crowning of the covered way of the ravelin to have been begun on the 13th or 14th night. It is continued right and left, always leaving 6 yards parapet along the crest of the original glacis. Some traverses, constructed whenever necessary, will protect the besiegers from the enfilade and reverse fire of the bastions and collateral ravelins. The width of the trench is 12 feet, except at the points where batteries are to be constructed, in which points it is 24 feet; it is executed by a process called *half-double sap*. The sap is carried on as a double sap, except that the gabions on the reverse side are filled with sandbags, and when the traverses are completed, those gabions are removed.

To prevent offensive returns in the salient places of arms, and to render dangerous the access of the defenders to the re-entering places of arms, a sap is often carried across the terreplein, to be transformed into a breastwork for a few riflemen, who will fire across the ditch.

At the same time saps are carried to the covered way of the bastions, so that on the 15th the re-entering places of arms are crowned.

If, however, the garrison defends itself vigorously, the advance on the re-entering places of arms might be attended with danger, in which case a fourth parallel is found necessary, and as it would mask the mortar batteries, these are brought forward.

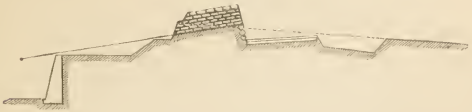
(219). The same day, counter-batteries (2, 2, 2, fig. 466) and breaching batteries (1, 1, 1, fig. 466) are constructed, and a descent into the ditch begun.

The counter-batteries at the salient of the covered way of the ravelin are intended to fire across the ditch to destroy the guns that flank it on the faces of the bastions. They may be completed in 15 hours, and when the defence is silenced they may open a breach on the faces themselves. The counter-batteries

at the salients before the bastions are destined to silence the artillery of the flanks which defend the main ditch.

The breaching batteries are constructed opposite the point itself where the breach is to be made. In order to protect the gunners, the embrasures are

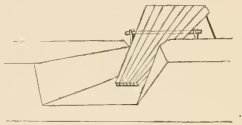
Fig. 468.



not cut entirely through: 3 feet of earth are left which are afterwards blown away by the first discharge; and it is usual to cover the neck by a moveable door or

Fig. 469.

Fig. 470.



some musket-proof apron; the second diagram represents a contrivance proposed by Albert Durer.

(220). In order to make a breach, Vauban recommended cutting a horizontal groove, and then firing by salvoes to bring down the masonry. Bousmard, (Chapter XXIII.) besides the horizontal groove, recommended two vertical ones, one at each extremity. The number of guns employed was at least 8, but since the experiments made at Metz in 1834, 1844, and at Bapeaume in 1847, it is admitted that four guns are sufficient, the 32-pounder or 24-pounder being most suitable. Firing at an angle less than 50° should be avoided, because the shots are liable to ricochet.

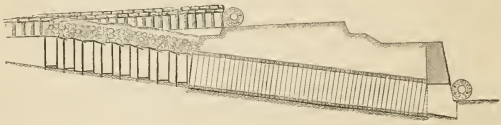
The method actually recommended consists in firing at the escarp six feet from the bottom of the ditch, or at $\frac{1}{3}$ of the revetment if the ditch is wet, so as to cut a horizontal groove through the masonry; vertical grooves more or less distant according to the nature and strength of the revetments are similarly cut, but are not necessary with hollow revetments. The masonry is afterwards brought down by firing salvoes. To cut the grooves, the charge should be $\frac{1}{3}$ the weight of the shot, whilst for the salvoes destined to produce a concussion, it should be

reduced to $\frac{1}{6}$ or $\frac{1}{8}$. The breach thus made is afterwards smoothed down to a slope of 45° by means of shells. The width should vary from 50 to 100 feet, to allow 25 or 50 men to mount abreast. When the breach is opened from a great distance, the quantity of metal is greatly increased, and the time required for the operation is prolonged. The results of the breaching operations at Badajoz, Ciudad Rodrigo, and San Sebastian, give the following mean:—

At 575 yards, a breach of 100 feet was opened by 10 guns in 83 hours, making an average of 92 shots per running foot. At Antwerp, 6 guns opened a breach 80 feet wide, in 34 hours, from a distance of 55 yards, the number of shots being 16 per foot. The experiments of Metz, give a breach 74 feet wide in $8\frac{3}{4}$ hours, by 4 guns at 34 yards, firing 4 shots per running foot. Those of Bapeaume give a breach of 66 feet, opened from 34 yards by 4 guns, with 24-pounders in 3 hours 50 minutes, firing altogether 190 shots; with 16-pounders in 4 hours, firing 285 shots; with 12-pounders in 4 hours 50 minutes, firing 380 shots. It may therefore be assumed, that under favourable circumstances, a breach can be made in 8 hours with 5 shots per running foot.

(221). The *descent into the ditch* is a difficult operation, which often delays the besiegers. The breaching batteries are ready on the 15th, and the breaches may be made on the 16th night, but it is not until the 19th that the descent can be completed. To make this descent, the besieger sinks a shaft in his crowning, just opposite the breach; and a gallery is driven (Chapter XVI.) to the counterscarp. Sometimes the descent is begun from a boyau run up for the purpose. The slope of this gallery is regulated according to the height of the counterscarp, so as to arrive

Fig. 471.



3 feet below the level of the ditch if dry, or 1 foot above the level of water if the ditch is wet. This slope should not be steeper than $\frac{1}{6}$, and if the ditch is deep, the shaft is sunk further off, in some zig-zag excavated for the purpose. This shaft is generally 10 feet square and at least 10 feet deep, in order to let 3 feet of earth remain untouched over the gallery. The dimensions of this gallery are $6\frac{1}{2}$ feet high by $7\frac{1}{2}$ feet. The side of the shaft opposite the gallery is sloped into a ramp and covered with *blind frames*, (as represented in figs. 472 and 473,) over which

Fig. 472.

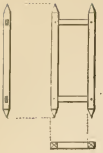
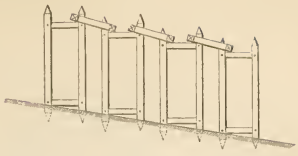


Fig. 473.



fascines and earth are laid to resist shells. When the ditches are shallow, it is impossible to leave 3 feet of earth above the gallery, and consequently, the whole descent must be blinded. It is necessary to make the descent opposite the breach, because the rubbish will give cover to the besiegers when crossing the ditch. It sometimes happens when the ditch is shallow, that a few shafts are sunk close to the counterscarp, and charges are lodged in chambers at their bottom, the explosion *blows in the counterscarp*, and the ruins join those of the breach, forming a ramp leading into the ditch.

(222). When the descent is completed, and when a reconnoissance has ascertained that the breach is practicable, the revetment of the counterscarp is cut through, and a sap is carried across the ditch to the foot of the breach.

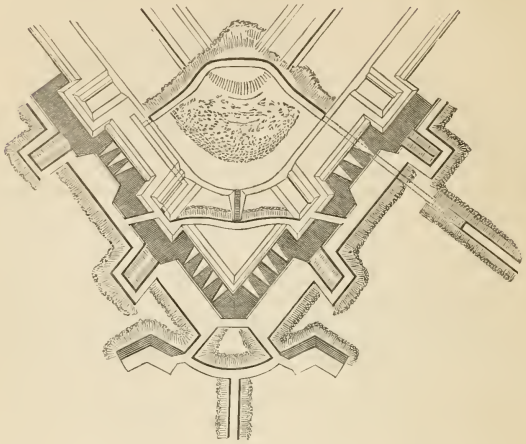
If the ditch is wet and the water stagnant, a causeway is formed across by means of fascines loaded with stones to make them sink, and an epaulment is raised on it.

When the water is running, and when the garrison has the power of filling and emptying the ditch at pleasure, the passage of the ditch becomes an operation of the utmost difficulty. In this case, if a dam cannot be made with fascines and sandbags to support the weight of water until it is allowed to run out through other channels, a bridge of some sort must be made. The small pontoon-bridge of Colonel Blanchard is recommended (167). The cask bridge of General Pasley has been proposed: casks, with their ends removed, are fixed together in sets of four. Each set is launched in the direction of the current, and is made to sink by means of sandbags: several sets are sunk until the upper ones appear on the surface, forming a flooring for the fascines.

Another method, employed at Philipsburg, in 1734, consists in the construction of a floating bridge of fascines: these are laid alternately crossing each other at right angles, with hurdles between, and fixed together with pickets. Sandbags sink the bridge to the level of water to prevent the defenders from setting fire to it. The epaulment is constructed considerably within the edge, and fresh raw hides cover the whole. If the current is strong, the bridge is kept in its place by anchors cast up the stream, and by props driven below.

Under ordinary circumstances, the operations of the siege are completed on the 19th night, and the assault is given at daybreak.

Fig. 474.



(223). This *assault* on the bastion is the most important operation of the siege; it is for it that all others have been made, and so many lives have been sacrificed. When all is ready for its execution, the general entrusted with its command ascertains that all the communications of trenches, descents, galleries, &c., are in good condition. The breaches are reconnoitred, and dispositions are carefully taken to avoid confusion; the strength of the column of assault, of the reserves, and of the working party, is determined. A little before the appointed time, the enfilade batteries and those of the covered way, keep up a vigorous cannonade, and once the signal given, the columns, eight or ten files in front, issue from the trenches, run across the ditch, and assault with fixed bayonets the defenders of the breaches. It is advisable to postpone this decisive movement till daybreak. After a success, great care is still necessary; pursuit must not be thought of, lest some ambuscade should have been prepared, and great circumspection must be shown in taking possession of the ramparts and of the town. During the assault,

the army is under arms, ready to prevent the garrison from making its escape, or to repel any attempt to relieve the place.

It should be borne in mind that the success of an assault greatly depends on the good order preserved among the troops, and that it is a fatal mistake to entrust the duty of an assault to detachments. The troops should be employed as organized with their own officers and non-commissioned officers.

When the assault is given to an outwork, or to a bastion containing interior retrenchments, it is necessary for the besieger to construct rapidly an intrenchment, generally a trench, on the captured breach, in order to maintain the position against recapture. This *lodgment*, as it is termed, can be made in two ways: either by a working party, which places the gabions on the breach whilst the storming party is fighting, or by a regular sap advancing from the ditch up the breach: in this method, which is recommended by Vauban, the breaching batteries are ready to open fire on the breach, should the garrison return to dislodge the sappers.

CHAPTER XIV.

DEFENCE OF A FORTRESS.

(224). When a garrison *receives information of the intention* of the enemy to lay siege to the place, it at once proceeds to prepare the means of resistance. The ditches in front of the place are filled, and the houses, walls, hedges, trees, &c., and all the agricultural buildings, levelled. Sometimes suburbs are intrenched, when they are likely to check the advance of the enemy.

The banquettes and interior slopes, ramps, &c., are repaired, platforms and traverses for guns are constructed, palisades are placed all along the banquette of the covered way, and the passages of traverses and sallyports shut with barriers: if possible, a second row of palisades is planted in the terreplein of the covered way.

At the same time, advanced posts are pushed forward on every road as far as prudence will permit, and their picquets and vedettes will prevent a surprise: they will be sufficiently strong to obstruct the investment and secure the arrival of convoys and reinforcements; their retreat should be secured; and signals should be provided, so as to receive intelligence from the neighbouring country. All provisions and materials likely to be of use for the defence should be brought in or destroyed.

When the advance ports are driven in, guns should be in readiness to fire from the salients of the covered way, and small detachments should be concealed in broken ground or ruined buildings, keeping themselves within the covered way at night, and during the day advancing a few hundred yards, they should endeavour to surprise the reconnoitring parties. The officers of artillery at the same time ascertain the range of the guns as compared with the distances of the surrounding objects, if it has not been done before.

At the same time tools and implements are collected, at the rate, for 1000 men, of 100 axes, 200 hatchets, 150 wheel-barrows, 10,000 sandbags, 200 chevaux-de-frise, &c.; wood is stored for stockades, galleries, mines, &c. At least 500 gabions, 2000 fascines, 600 hurdles, &c., are prepared for revetments.

(225). *When the investment is completed*, the defenders endeavour to ascertain on which front the attack is intended to be made, in order to delay the opening of the trenches: should they discover the time and place of the opening, as soon as the besieger begins, all the barbette batteries, and as many guns, howitzers, and mortars as can be brought to bear should keep up a vigorous fire; but when the parallel is completed, the firing should cease, as it would be a waste of ammunition.

Sorties of light troops are now made to impede the workmen, but at this period of the siege there is need of great caution: sorties should be made at several points against the works, and if they can reach the parallel, the working parties that accompany them will soon destroy one night's progress. As a general rule, sorties should only be made in force for the purpose of destroying a battery or a work which causes much harm to the defence.

The next care of the defence is to prepare the batteries of the front of attack, and erect traverses 18 feet thick between every two guns.

The positions destined for the enfilade and ricochet batteries of the besieger are easily known, and as many heavy guns, and more especially heavy mortars as can be spared, should be kept ready to concentrate their fire on each battery in succession, it being a fact well known at present that no battery can resist a well-directed fire from shells.

Embrasures are also cut through the parapets of collateral fronts having any view on the attack, and the guns are mounted only when wanted, so as to avoid unnecessary exposure.

(226). *After the besieger's batteries are erected* and armed, the defence will reserve its fire for a later period, and chiefly check their progress by musketry.

It is also during the same period that *fleches* and *counter approaches* are made outside, and *retrenchments* and *blindages* constructed inside the place.

Fleches are small redans of faces, from 20 to 40 yards in length, rapidly thrown up in the capital, at the foot of the glacis; their terreplein is generally sunken, and they derive support from the works in rear or from other fleches.

Lines of *counter approach*, a sort of trench or sap, are excavated in front of the glacis, to be connected with batteries hastily thrown up on positions where the zig-zags can be enfiladed; they generally debouch from the covered way of the ravelin, collateral to those attacked.

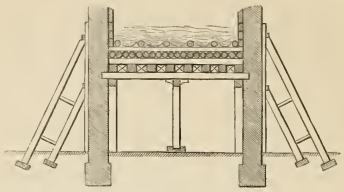
The establishment of the Russian rifle-pits, and the erection of their works on the Mamelon, in February, 1855, are instances of what a determined garrison can do to impede the progress of the besiegers.

The retrenchments in bastions are generally a permanent construction (chap. XX.) but when none exist on the front attacked, the garrison should organize such works as time will permit, either a trench across the gorge of ravelins and bastions, or a gabionnade, a stockade, or a palisade.

As for the blindages, they require especial care; they are bomb-proof shelters for the troops, guns, magazines, cisterns, hospitals, &c.

When the barracks, magazines, &c., have not been built shell-proof, the best thing to do is to demolish the upper stories, and cover the first floor with two courses of joists close together, and crossing each other, and to put over it 4 or 5 feet of earth. Under the beams of this floor, girders, some 12 inches square, are

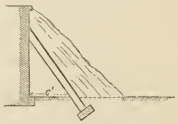
Fig. 475.



placed 10 feet apart, and are supported by vertical posts as well as by the walls into which they are inserted. The windows and door-ways are protected by inclined beams; and whenever there is a doubt as to the strength of the walls, they are blinded by inclined beams covered with earth, or supported inside by props.

Should there be no building fit to be blinded, the defenders construct a leaning blindage behind some strong wall or behind some counterscarp, the timbers of which being square, are inclined at 60°. They rest on a sleeper, are fastened by joists, and are covered with earth.

Fig. 476.



Or a double blindage is constructed, either in the form of an inversed V, or by

Fig. 477.

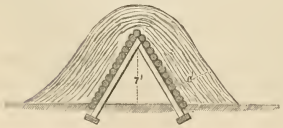
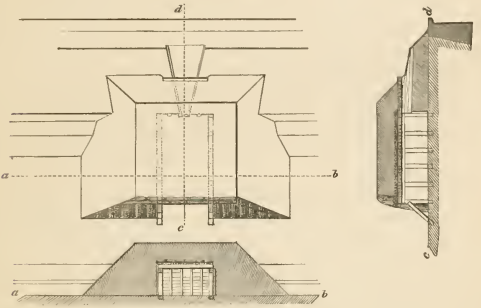


Fig. 478.

some construction under a traverse, or even by covering the space between two traverses with beams and earth.

The guns near the salients of the ravelin and the bastion are generally blinded, and the besieger will have great trouble to silence them. Such blindages are constructed with strong posts, 1 foot square and 7 feet high, placed vertically on both sides of the platforms, and supporting a roof of beams covered with fascines, and 4 or 5 feet of earth. The sides exposed to enfilade are protected by thick mounds of earth.

Fig. 479.



(227). *After the completion of the second parallel,* the chief effort of the defence must be to direct such a fire of musketry on the approach as will prevent the besiegers from using the flying sap: loopholes with sandbags are constructed on the parapets for riflemen; and if a field gun can be brought to bear on the head of the saps, the latter will be much retarded.

The guns ricochet along the capitals with shot and shells.

Some mortars placed at the salients of the covered way will fire stones, and as many mortars as possible will fire shells and grenades into the trenches. The sorties become more and more active; they are directed against the head of the sap, and endeavour to interrupt the construction of the third parallel.

When this is finished, the garrison must expect an attack on the covered way, and prepare for it; it is recommended not to await the besiegers in the salient places of arms, but to retire to the re-entering places, after having given them a volley, thereby unmasking the covered way to the fire of the works in rear.

Sorties are prepared in these re-entering places in case the assailants should waver.

If the covered way is attacked by the regular process, the advance is checked by the vertical and musketry fire, by blinded batteries erected in collateral salients, and even by guns not seen by the attack, and firing at ricochet in the direction of the prolongations of the trenches. Riflemen continue their fire.

(228). *After the crowning of the covered way*, the defence will lose no opportunity of impeding the construction of the counter and breaching batteries; shells are fired into their parapets, and marksmen pick off the gunners. The batteries or the flanks are blinded, and a vigorous vertical fire is kept up on the entrance of the descent into the ditch. The collateral flanks contribute their fire. Sorties are made into the ditch to resist its passage, and all the fire of musketry and artillery that can be had is directed against this part. Should the ditch be provided with sluices for filling or emptying at pleasure, the advance of the besiegers may be checked for a time: the garrison first defends the ditch when dry, and when the enemy reaches the foot of the breach, water is let in, and left there until the besieger has again crossed, when the ditch is suddenly laid dry. If the ditch is permanently wet, the defence will throw combustible matter, shells, &c., on the dams of fascines.

(229). *The breach at last is practicable*, and the flanks are silenced, and the only resource left to the garrison is vigorously to defend the breaches; there all its energy is called into play; fires are lighted on their slopes, and kept burning by a continual supply of fascines, &c. At night, quantities of crows' feet and broken glass are spread; chevaux-de-frise, abattis, &c., are placed, and barrels of powder and shells are duly prepared to be lighted and rolled on the columns of assault when they reach the foot of the breach: fougasses are also prepared, and any means that the garrison can dispose of. There are instances of breaches being defended by fixing on them planks rendered slippery with soap, and of assaulting columns being repulsed by the fall of several bee-hives amidst their ranks.

If these means prove insufficient, and if no gun has been saved on the flanks, the last resource consists in selecting the most resolute men to charge the assailants. These troops are, if possible, covered with cuirasses. The first rank, armed with long pikes, kneels, whilst the rear rank pours a volley on the enemy; grenades, &c., being thrown upon both sides of the breach by special detachments. Then they charge with fixed bayonets, and the reserve comes to their support. If driven back and pursued actively, field artillery, kept in readiness, may still check the advance of the besieger.

The defence of the breaches is one of the most important—not to say the chief resource, of a besieged fortress; and a garrison should never give way to dis-

couragement because the ramparts have been battered down; it will still fight at a great advantage, and there are many instances to be found in military history of a successful resistance.

The defence of Rhodes in 1521, besieged by Solyman, shows what a small but determined garrison can do against a much superior foe.

When the Constable of Bourbon had ruined the ramparts of Marseilles in 1544, the breaches were so skilfully and gallantly defended, that the Imperialists were compelled to raise the siege.

At Maestricht, in 1676, a French garrison of 6000 men fought so vigorously for the defence of the breaches, that the Prince of Orange was obliged to give up any further attempt, and to retire with a loss of 12,000 men.

The breaches of Turin (1706) were defended by large fires—and successfully, too.

St. Jean d'Acre was besieged in 1799 by Napoleon, and although the ramparts had been overthrown, all assaults proved unsuccessful, and the French had to retire, leaving their guns behind them.

In many other instances the Turks have given us a good example to follow, especially in the Russian campaign of 1828.

At Badajoz, in 1811, the English were repulsed at every assault. In 1812, the same place again resisted, and if General Picton had not surprised the Castle of San Cristoval, the vigorous defence of the breaches would again have saved the place.

Even when the besiegers have gained a footing in a fortress, all hope of further resistance is not lost.

Prince Eugene, at Cremona, was obliged to retreat; so were the English at Berg-op-Zoom. At Saragossa, in 1809, the French had to besiege almost every house.

The governor of a place cannot capitulate before having resisted at least one assault on the bastion. His honour is at stake. Want of arms and ammunition, or almost complete destruction of the garrison, are the only reasons that should induce him to surrender. The task and responsibility are immense, and none but men of great skill and energy are fit for that post. To prolong the resistance at all risks must be his motto. When all fails, then he must endeavour to obtain good terms, and if they are refused, his forlorn hope is to attempt an evacuation, and to force his way through the investment.

(230). Ever since the middle of the last century, it has been considered advisable that the governor of a besieged fortress should keep a "journal of siege." This journal contains the names and grades of all the officers who command the besieging army in addition to those of the garrison, those of the regiments or their distinctive numbers, &c. It is divided into two columns: one for the attack, the other for the defence.

All the operations and events are recorded day by day: the number of working parties, the time of execution, nature and purpose of the works; the numbers of wounded and killed, the names of the men who distinguish themselves, &c.

These journals are excellent guides for the study of the science: by means of them we can ascertain the time necessary for the execution of the parallels, batteries, mines, &c., and form bases from which to calculate the probable duration of the siege of a fortress, the quantity of ammunition that will probably be required, &c.

CHAPTER XV.

FORCES EMPLOYED IN A SIEGE.

(231). The *armament* of fortresses depends much on the size of the works and on the locality in which they stand, and no fixed rule has been adopted to compute the amount of ordnance necessary for the defence. Vauban wanted 10 guns per bastion, and 5 mortars or pierriers, making 90 pieces for a hexagon. Cormontaingne fixed a minimum of 36 and a maximum of 46 for the same polygon. In France they now divide their fortresses into three classes, and allot 110 pieces for the 1st class (10 fronts or more); 70 for the 2nd class (7 to 10 fronts); 30 for the 3rd class (4 to 6 sides). This armament is independent of 10 pieces per bastion, which are intended to provide for the immediate security of the place. At this rate, a hexagon would require 90 pieces. Of this ordnance 54 per cent. are guns, 26 per cent. howitzers, and 20 per cent. mortars. In this country, the best authorities calculate the armament at the rate of 8 pieces for the immediate security, and 150 pieces for a place of 10 fronts or upwards, 100 for a place of 6 to 10 fronts, and 50 pieces for a place of 4 or 5 sides. The hexagon would thus require 148 pieces.

Some authors fix the proportion of the several natures of ordnance at 50 per cent. of heavy guns; 10 per cent. howitzers; 30 per cent. mortars, 10 per cent. field guns; but it is generally admitted that a greater percentage of howitzers is necessary, because shells do more against earthworks than solid shots.

The best ordnance for the defence of a fortress are for solid shot: the two kinds of 68-pounders, the 32-pounders of 58, 56, and 50 cwt. respectively, and the 24-pounders of 50 cwt.; for shells, the 10-inch shell gun, the four kinds of 8-inch guns, the 10-inch howitzer, the 8-inch howitzer, and the 32-pounder of 25 cwt. Of mortars the best are the 13, 10, and 8-inch. The small brass mortars of $5\frac{1}{2}$ and $4\frac{2}{5}$-inch, are recommended for firing on the working parties of the besieger.

There are generally in fortresses wooden standing garrison carriages, but any carriage will answer the purpose, and about one-third as many more should be

kept in store to replace those that may be destroyed. The platforms, wood or stone, are usually on the ground, except at the salients, where low traversing platforms are necessary. For the transport of this ordnance, sling carts or sling wagons for the guns, and trench carts for the mortars are provided. Gyns and sheers are also necessary.

(232). With regard to the *ammunition*, the quantity required depends on the duration of the siege; it is therefore very variable. However, it is usual to reckon 700 rounds for each gun, and 500 for each mortar of a 1st class fortress; 600 and 400 for those of a 2nd class; and 500 and 300 for those of a 3rd class. In addition to these there should be a certain quantity of shrapnel shells for the guns, and of light balls and pound shot for the mortars.

(233). To compute the *strength* of the *garrison*, it is usual to divide the troops into thirds, one third on the front of attack, one third at bivouac and ready at a moment's notice, and one third at rest, although towards the latter period of the siege the whole garrison is constantly required on the ramparts.

A place can always be defended, whatever be its garrison, yet as a force too numerous would prove a great inconvenience in a fortress, it is advisable to find a minimum: troops which can be more usefully employed in the field will not thus be wasted. The calculation for a hexagon will give an idea of the principle.

When the enemy arrives before the place, the garrison has no other duty than that of putting the place into a state of defence, and sending out patrols and reconnoitring parties; nor will its service become heavy until the besieger has begun sapping. Now it has been shown by experience that if 60 shots are fired per minute on the head of an attack, the besieger must have recourse to sapping: for the 3 salients we require in the covered way 180 men, but as they cannot fire constantly, we reckon three times that number, or 540. The ravelin of attack requires 150 men.

For the repairs of parapets, &c., we must allow 100 men, and as many more for the fatigue party helping the gunners. For the fronts not exposed to attack, sentries are necessary, and 100 men to contribute to the various posts are not too many.

Adding 100 men for the collateral fronts, this will make altogether 1090 infantry, and for the three reliefs 3270. Giving 300 for artillery, 120 for engineers and staff, and 80 for cavalry, the garrison will amount to 3770 men, a little more than 600 men per bastion. As a rule, therefore, we can fix the garrison of a square, pentagon or hexagon, at 4000 men.

Vauban required 600 infantry per bastion, plus 60 cavalry, and 100 for staff, artillery, and engineers, altogether 4560 for a hexagon. Cormontaingne demanded very nearly the same number, 4100.

For the security of a place 440 men per bastion (of which 350 infantry, 10

cavalry, 60 artillery, and 20 engineers) are sufficient. For polygons of more than 6 sides, the garrison for the defence is reckoned at 440 per bastion, and double that number for the fronts susceptible of attack.

Great support from the inhabitants cannot be expected; only one-sixth of them are fit for service, and one-eighteenth only can be employed at a time. The maximum of a garrison is determined by the capacity of the barracks, casemates, &c., and by the amount of provisions. A representing the number of rations, and B the strength of the garrison, $\frac{A}{B}$ must be greater than the usual length of a siege.

(234). The stores for the garrison, including ammunition for musketry, tools, provisions, &c., are placed in magazines for which bombproof shelter should be prepared. It is customary to provide surplus arms at the rate of one for every 4 men; wall pieces 10 per bastion, musket-ball ammunition 500 per man; hand grenades 10 ditto; gunpowder in barrels 2½lbs. per man, lead 10lbs. ditto; cartridge paper 1¼ quires. Besides the engineer and artillery stores, felling axes, bill hooks, pickaxes, shovels, and hand saws are provided, at the rate of one of each for 16 men.

Although the governor of a fortress threatened with a siege warns the inhabitants to store up provisions, most of them are unable to maintain themselves, and the government has to distribute rations to them as well as to the garrison. The *Aide Memoire* for military sciences gives the quantity and the bulk of the provisions necessary for a siege of 56 days per 100 men.

		Cubic feet			Cubic feet.
Flour or meal	2200lbs.	76	Cocoa	700lbs.	41
Biscuit	5600lbs.	358	Soft sugar	525lbs.	14
Salted beef	5600lbs.	216	Spirits	1400 pints	56
or pork	5600lbs.	202	or wine	5600 pints	224
Rice	2200lbs.	70	Vinegar	200 pints	8
or peas	1400 pints	54			

The fuel for cooking, Wood	1200	Cubic feet.
or coals, 7 tons	350	„
or turf	3000	„
Oil, 40 Gallons	4	„
Candles, 40lbs.	3	„
Forage for 20 horses, Hay, 7 tons	4000	„
Barley, 7200lbs.	160	„
or Oats, 7200lbs.	250	„
Straw as hay, 7 tons	4000	„

(235). *The force of a besieging army* depends upon the strength of the

garrison, the *morale* of both armies, and the season of the year—elements which cannot form the basis of exact calculations.

In some instances two armies are necessary; one of *observation* to cover the siege, and prevent any attempt on the part of the enemy to relieve; the other to besiege. To this latter army alone we shall direct our attention.

It must provide men for the excavation and guard of the trenches, the construction of batteries, and the investment of the whole circumference of the place; for the police of the camp, the outposts, patrols, extra duties, &c.; also a proper number of sappers and miners, gunners, &c.

Supposing the attack to be directed against a front of a hexagon, the first parallel and its communication on the rear occupying a development of nearly 6000 yards would require 3000 men, but during the first night not more than 4800 yards are excavated, and 2400 men are sufficient, and this number will remain the same till the opening of the second parallel; as its development is less, fewer men will be wanted. Towards the latter part of the siege the number will still decrease, so that in general we may compute the working party at 2000 men. In order that the siege may be conducted with energy let us allow four reliefs, and we must then have 8000 men. The posts for the investment are at 3000 yards from the salients of the place, and as these are already at 500 yards from the centre, there is for the hexagon a perimeter of 21,000 yards; subtracting 6000 yards for the first parallel, the investment must occupy 15,000 yards, which at the rate of 200 men per thousand yards, give 3000 men.

The guard of the trenches amounting to $\frac{1}{4}$ of the garrison, makes 3000 men for a garrison of 4000 men, and at three reliefs it implies 9000 men in all.

Adding to those 2000 men for four reliefs of fatigue parties, allowing 3000 for artillery, 300 engineers, 600 cavalry, the total force will amount to 25,900 men or more than six times the garrison.

When the garrison is stronger, the guard of the trenches is the only item in the above calculation that will require to be increased, and the whole of the besieger's force need not be increased in proportion to that of the garrison. It is admitted now that for a garrison of 15,000 men, the besieging army should be five times larger, six times for 10,000, seven times for 5000, and eight times for 3000.

Although it is a difficult matter to fix any limit to the force of a besieging army when it has to prepare against the diversions of an enemy, yet it may be said that attempts with a force less than 60,000 men are not likely to prove successful.

In 1793, the King of Prussia required 100,000 to besiege Mayence. The same year, the English and Austrians had 120,000 men before Valenciennes; and the Prince of Coburg besieged Le Quesnoy with 60,000; but the Duke of York could not invest Dunkirk and Bergues with 50,000.

It is true that in 1796 Bonaparte invested Mantua with 20,000 men, half of which were employed in the siege; and that at Saragossa, in 1809, the French had but 35,000 men; but again, at Silistria, in 1854, the Russians had 70,000 men.

(236). The state, armament and force of the garrison of a fortress, and the facilities of transport offered by the country in which the siege is carried, will exercise a great influence on the selection of the kind of ordnance and of the force of the *battering train*. Different numbers have at various times been fixed. Thus—Vauban required 160 pieces, of which 70 per cent were guns, 15 per cent howitzers, 15 per cent. pierriers; Bousmard required 168 pieces, of which 50 per cent were guns, 18 per cent howitzers, 22 per cent mortars, 10 per cent pierriers; Gassendi required 160 pieces, of which 62 per cent were guns, 15 per cent howitzers, 15 per cent mortars, 8 per cent pierriers.

A committee of artillery in 1819, recommended for the siege of a first-class fortress 140 pieces, *i.e.* 60 guns, 15 howitzers, 25 mortars, and 40 small brass mortars.

Sir John Jones demanded 106 pieces: 40 guns, 20 howitzers, and 46 mortars.

The regular battering train of Austria includes 178 pieces, of which 45 per cent are guns, 13 per cent howitzers, 35 per cent mortars, 7 per cent pierriers. That of Prussia 142 pieces, 60 per cent guns, 15 per cent howitzers, 20 per cent mortars, and 5 per cent pierriers. In France, previous to 1656, the number of pieces was 162; it is now 175, thus divided: 80 guns, 40 howitzers, and 55 mortars.

In England, the maximum equipment is generally admitted to be 160 pieces, of which 60 are guns, 40 howitzers, 20 mortars, and 40 small brass mortars. For a fortress of 2nd, 3rd, or 4th class, this number is reduced. Some officers, instead of dividing this maximum, prefer to adopt a minimum of 40 pieces, and to double, triple, or quadruple it. The proportion recommended is: guns $\frac{1}{2}$, howitzers, or shell guns $\frac{1}{3}$, mortars $\frac{1}{6}$, besides an equal number of small brass guns. General Burgoyne considers 25 pieces the minimum battering train for the reduction of forts, and it may be added that no serious attempt should be made against a front with less than 60 pieces.

Until the adoption of rifled guns alters the actual composition of the equipment, the best ordnance is the 32-pounder of 50 cwt. which has superseded the 24-pounder since the Crimean war, the 8 inch shell gun which also proved better than the 10 inch, and 8 inch howitzers hitherto employed, and the 10 inch and 8 inch iron mortars.

It is understood that each gun has its carriage, each mortar its bed, and that $\frac{1}{10}$ extra mountings are allowed for losses: sling and platform-waggons for

transport of ordnance, Flanders waggons, trench and hand carts for the conveyance of ammunition and store; triangle gyns, &c., are also included in the equipment.

As for the number of men necessary for that artillery, it is usual to compute it at 2700, and at 2975 including extra hands for laboratory, casualties, &c.

During the reign of Louis XIV., the battering trains were more numerous than in the wars at the beginning of this century. At the siege of Namur (1692) the besiegers had 260 guns; at Charleroy (1693), 210; at Turin (1706), 251; at Menin (1706), 116; at Lille (1708), 200; at Douai (1710), 368.

The following table of some remarkable sieges compiled from the French Aide-Memoire, will give an idea of the amount of artillery employed in modern times.

		Defence.	Attack.			Defence.	Attack.
1793	Valenciennes ...	175	167	1810	Tortosa	177	50
1794	Neuss	200	40	1811	Tarragona	290	66
1806	Gacta	171	109	1811	Badajoz	170	54
1807	Breslau	300	38	1812	Ciudad Rodrigo ...	119	68
1807	Schweidnitz ...	250	43	1812	Badajoz	140	78
1808	Rosas	58	53	1813	San Sebastian ...	63	88
1808	Girona	168	71	1828	Varna	100	45
1810	Lerida	110	40	1829	Silistria	238	88
1810	Ciudad Rodrigo ...	86	50	1832	Antwerp	145	148
1810	Almeida	98	67				

(237). With regard to the amount of ammunition, the number of rounds per piece should not exceed that which is calculated to render it unserviceable: 1500 rounds per gun, exclusive of case, shrapnel and carcasse, is the utmost that may be reckoned. The following proportion for a battering train of a hundred pieces, is given as a fair allowance.

For a 32-pounder, 1000 round shots, 100 common shells, 50 shrapnels, 50 grape or canister.

For an 8 inch gun, 200 hollow shots, 600 common shells, 50 shrapnels, and 50 grape or canister.

For a 10 inch mortar, 600 common shells, 50 pound shot, 10 carcasses; small brass mortars, 300 common shells.

The quantity of ammunition provided for a siege, and the amount actually consumed, vary widely, the place itself often providing the besieger with shot, as at Tarragona, where $\frac{1}{3}$ of the projectiles came from the defenders. In the annexed table, we give the number of rounds calculated at the rate fixed above, and compare it with that of the rounds actually fired.

Gaeta (1806) . .	100	pieces	(84,500),	fired	68,700	in	11	days.
Girona (1808) . . .	71	„	(45,995)	„	99,900	in	104	„
Lerida (1810) . . .	40	„	(33,800)	„	9000	in	15	„
Ciudad Rodrigo (1810) .	50	„	(42,250)	„	17,961	in	16	„
Almeida (1810) . .	67	„	(56,615)	„	10,000	in	12	„
Tarragona (1811) . .	66	„	(55,770)	„	42,000	in	28	„
Badajoz (1812) . . .	78	„	(65,910)	„	35,346	in	11	„
San Sebastian (1813) .	88	„	(74,360)	„	70,831	in	36	„
Antwerp (1832) . .	148	„	(125,060)	„	64,392	in	19	„

CHAPTER XVI.

MILITARY MINING.

SECTION I.—Mines.

(238). *A military mine* is a subterranean excavation in which a charge of powder is deposited, for the purpose of blowing up the enemy's troops or works, or of destroying abandoned works to prevent the enemy making use of them.

Offensive mines, or simply *mines*, are those executed by the besieger, and *counter-mines* those by the besieged.

Before the invention of gunpowder, *mines* were excavations or galleries under the walls of a fortress; the foundations were supported by props, and when completed, the excavation was filled with dry wood, and the timber set fire to. The props being burnt, the walls gave way and opened a breach. The defenders also excavated *counter-mines* to overthrow the machines of the besieger, and to prevent him from executing his mines.

Powder was first employed for this purpose in 1503, by Peter Navarro, at the siege of the Castel del Uovo, at Naples.

The excavations, when vertical, are called *shafts;* when horizontal, *galleries* or *branches*, according to their size.

(239). Shafts are generally rectangular, 3 feet by 4; but sometimes elliptical.

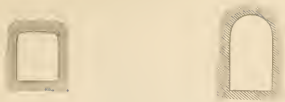
Branches are from 2½ to 3 feet wide, and from 3½ to 4 feet high.

Small galleries are 3 feet wide and 4½ high; great galleries 6 feet 6 inches wide, and 7 feet 6 inches high.

(240). The best soils for mining are those consisting of chalk, and also those of fine sand when cemented by clay or earthy matter. Clayey soils are the worst.

When excavating in favourable soil, or in ordinary soil, at a small depth, the shaft requires no wood support, and is best made elliptical; the galleries can be excavated either in rectangular form, or in that of an arch if they are intended to stand for any considerable time.

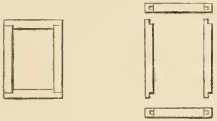
Fig. 480.



To prevent mines excavated in bad soils from falling in, the earth should be supported either by wooden *frames* or by cases, which are readily made from the floor of any house.

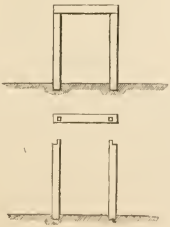
(241). *Frames* are composed of four pieces, two long and two short; the long ones are of the same section throughout, but the short ones are notched at each end, so as to form shoulders for the long pieces, and to prevent them from parting; tenons and mortises are cut near the ends of the pieces. They are made of scantling 3 by $4\frac{1}{2}$ inches.

Fig. 481.



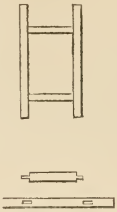
Frames for galleries and branches are composed of two upright pieces called stanchions, and one top piece, called capsill; the stanchions are usually let into the ground a few inches, and the capsill is placed over them, its mortises receiving the tenons of the stanchions. The stanchions are 4 inches square for branches, 5 inches for common galleries, and from 6 to 7 inches for great galleries, the capsill having the same width, but a depth greater by $\frac{1}{4}$ or $\frac{1}{3}$.

Fig. 482.



Besides these frames, it is necessary to have one for the top; the dimensions in the clear are the same, but the ends of the long pieces project one foot each way.

Fig. 483.



They are fixed by tenons and mortises, as represented in the diagram; the same material may be used as with the common frames, but the position is reversed, because in the top frame the depth should be greater than the width.

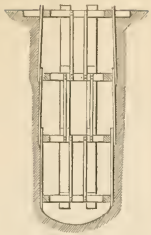
Together with these frames, sheetings or planks are employed 1 or 1½ inch thick for the shafts or the sides of the galleries, and 2 or 2½ inches for the top of the galleries.

(242). *To sink a shaft*, a pit, somewhat wider than the dimensions intended to be preserved, is cut vertically down to the depth of 2 or 3 feet, when a top frame is placed over it, its projecting ends buried to their own depth in the ground.

Fig. 484.

The excavation is then continued to 4 feet, when a second frame is placed horizontally at the bottom, having its sides vertically under those of the first; and the sheetings are let down between the sides of the pit, and the exterior of both frames. In general, two planks are sufficient even in soil of ordinary tenacity; they are pressed home close to the top frame, and at the lower one they are kept out by wedges. The two frames are fastened together by four braces of wood, or by means of ropes.

Fig. 485.



The excavation is then continued to 4 feet, when another frame is placed at the bottom, and the wedges being removed, the planks are let in between the first set and the frame. The work proceeds in this manner until the last frame is placed at about 9 or 12 inches above the level of the capsill of the intended gallery, and the excavation is continued down to the level of the bottom of the gallery, three sides only being now sheeted.

When the shaft is sunk with a view to commence a gallery, care is taken that the sides of the top frame agree with the sides of the proposed gallery.

(243). *The gallery is excavated* in a similar manner, the first frame being carefully fixed on the sides of the shaft, and the direction of the centre of the gallery being marked by two pickets, which afterwards serve to dress it.

Fig. 486.

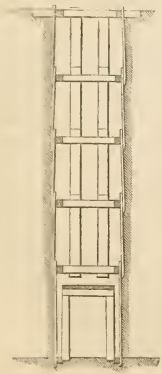
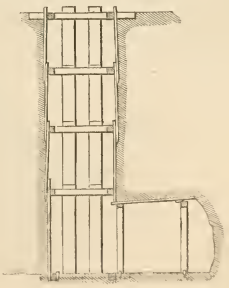


Fig. 487.

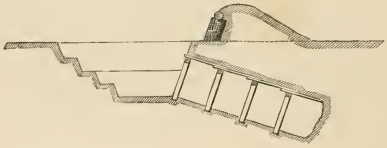


In great galleries, or in all galleries in bad soil, sleepers or ground sills are laid beneath the ends of each of the frames, to prevent the stanchions from sinking unequally; they are buried to their own depth.

Fig. 488.

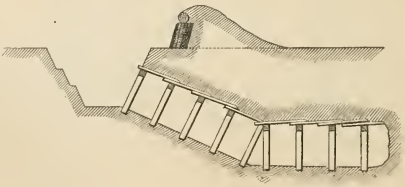
(244). When a *gallery* is required to incline downwards, instead of sinking a shaft, it is preferable to commence it from behind a cover, the parapet of a sap for instance. The trench is deepened so as to allow 3 feet of earth above the top of the gallery, and the direction being marked by two pickets, the first frame is placed, leaning forward in a direction perpendicular to the descent. The work proceeds as in the general case, the distance between the stanchions being measured along the slope, and not horizontally, in order to use the same sheetings.

Fig. 489.



(245). In changing the *inclined direction of a gallery* to a *horizontal course*, the first vertical frame must be supported by struts parallel to the stanchions of the last oblique frame, because the weight of the earth tends to overset the frames.

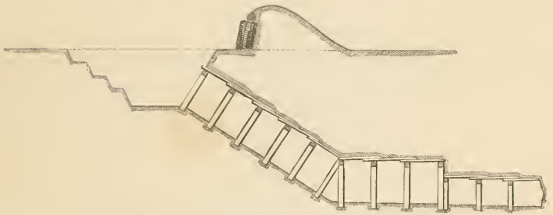
Fig. 490.



(246). *The branches* are executed in the same manner, except that the stanchions need not be inserted so deep into the ground. An oblique frame of larger dimension is generally used and dressed with the side of the gallery.

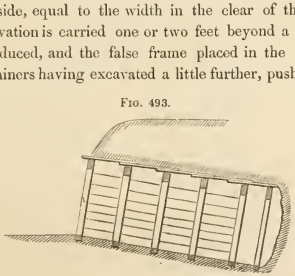
Fig. 491.

Fig. 492.



(247). When the soil is not favourable, the sides of the shaft and galleries should be entirely sheeted; when the soil is very bad, the miners make use of *false frames*, or frames of the usual height, but narrower, and exactly of a width from outside to outside, equal to the width in the clear of the ordinary frames. As soon as the excavation is carried one or two feet beyond a regular frame, the top sheeting is introduced, and the false frame placed in the same manner as a common one; the miners having excavated a little further, push on the false frame,

Fig. 493.

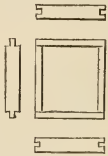


never allowing the top sheeting to project more than six inches beyond it. To avoid wedging the sheeting, the false frame is made 2 inches higher, thereby giving an upward splay to the planks.

(248). The method of mining with frames is now superseded by the method of *casing*, because it produces a larger gallery or shaft by means of a smaller excavation, involves no trouble of measuring, plumbing, or levelling, requires no false frame in bad soil, no sheeting, no brace or rope to fasten the shaft's frames, and especially because it enables the work to proceed much more rapidly, and allows of its being carried on without danger in soils quite unfit to be worked with frames.

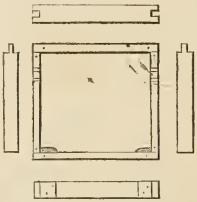
(249). *A case* consists of four pieces of two-inch planks, two side pieces or stanchions, and two end pieces or cap, and ground sills, fixed by tenons and mortises 2 inches long, and 3 inches wide. A couple of rivets prevents them from splitting.

Fig. 494



The planks are 11 inches wide. For great galleries more strength is required, and the ground sills are 3 inches, the stanchions 4 inches, and the cap sills 5 inches thick.

Fig. 495.



The usual dimensions of cases are: shaft, 4 feet 6 inches by 3 feet 6 inches; great gallery, 7 feet 6 inches by 6 feet 6 inches; branch gallery, 4 feet 6 by 3 feet; small branch, 2 feet 6 inches by 3 feet 7 inches.

The stanchions for great galleries have no tenons at the lower end, but are kept in their position by blocks of elm nailed to the ends of the ground sills.

(250). *To sink a shaft* in loose soil, an excavation of one foot is made and the first case is placed; the second and all the others are placed in the same way, but instead of excavating to the like depth of one foot on the whole area, the miner excavates first for one end only of each new frame, then for the other end, next for one side, and then for the other.

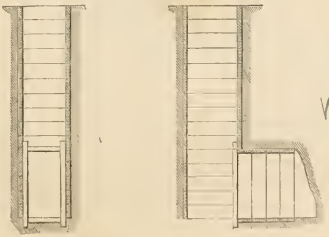
Fig. 496.

The shaft is completed thus to the level of the bottom of the intended gallery, and at starting, two sides of the cases are placed exactly parallel to the proposed direction of the gallery. To commence this, a fixed frame similar to a doorpost

Fig. 497.

is set up on the side of the shaft with its sill below the level of the intended floor, fitting exactly right and left: it is intended to support the lower casing of the shaft after the pieces are removed to excavate the gallery, its width and height being equal to, or an inch greater than those of the gallery. It is placed in its position after the miner has removed the lowest end piece, and the one immediately above

Fig. 498.



it. The other ends or side pieces are removed afterwards, until there is sufficient height for the gallery.

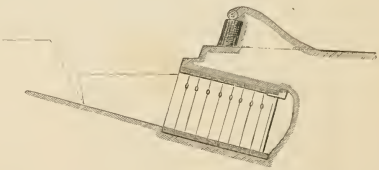
The ground sill of each case is first laid, then the stanchions and the cap. The cap is fitted first with the tenon of one stanchion, and either the other end is raised up, or the head of the second stanchion is pushed out two inches beyond its proper place to adjust the tenon and mortise of that side, care being taken to cut away no more earth than is necessary.

(251). *Great galleries* serve chiefly for a descent into the ditch, and may slope 1 foot in 4. They are commenced by cutting a shaft 10 feet square at the bottom and 10 feet deep, and from the bottom a ramp is cut to the rear as a means of communication. This depth will leave 3 feet of earth over the cap of the gallery. The cases are placed perpendicularly to the slope. In making these galleries, after a case is set, a couple of *crutches* of the form of a T are used, the

Fig. 499.

shanks of which rest on the last sill laid, whilst their heads, two feet long, project 1 foot beyond the last cap. The excavation being made wide enough to receive the next cap, this is laid on and supported by the projecting ends of the crutches;

Fig. 500.



the excavation is next continued below to allow of the placing of the sill and the stanchions of the new case one after another. The crutches being moved on to this new sill, the process begins afresh. The head of the crutch is braced to the shank by an iron bolt to be made steady; the foot is kept steady by driving a wedge into a groove cut in it, and the projecting end of the head is about an inch

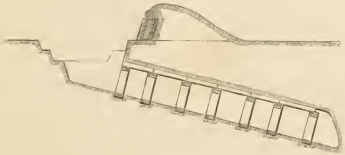
thicker, to enable each successive cap to stand at first a little higher than its final level. Notches 1 inch deep and 6 inches long, are cut on each side, about a foot from the top of these stanchions to allow of a man's hand passing through to adjust them.

(252). Galleries once begun in loose soil should be carried on without intermission. *When the soil is favourable* partial casing only is necessary, and the cases are introduced at clear intervals of 3 or 4 feet, they are either notched into the earth, or the end pieces are supported by pickets driven horizontally under them.

Fig. 501.

In making *small galleries*, the same method is adopted, and by laying the cases at 2 feet 4 inches and 3 feet 6 inches in the clear, alternately, we can put a cap and sill on the top of the short bays and two stanchions on the wider one, these being fixed to the sills by their tenons: 24 feet of gallery can thus be made with ten cases, seven acting as frames, three as sheeting.

Fig. 502.



(253). *In changing the direction* of descending galleries, the cap of the first level case should abut against the last descending case, the triangular spaces at the bottom being filled with pieces of board. When the direction of the gallery turns, the cases touch on one side, not on the other, and the spaces left at the top and the side are also covered with boards.

Fig. 503.

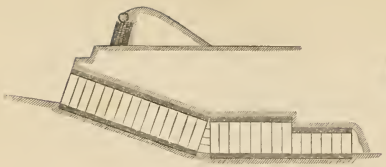
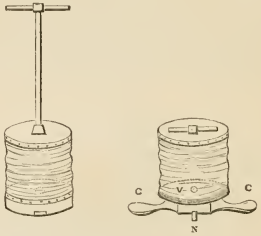


Fig. 504.

When the galleries to be excavated are long, two or more shafts are sunk 50 or 60 yards apart, their axis being in a vertical plane. Should the ground be uneven, it is levelled with a theodolite, the respective depths are calculated, and the miners having sunk the shafts, advance towards each other guided by the compass.

(254). After a gallery has been driven to some distance, forty or fifty yards, the miner cannot proceed any further unless a *supply of fresh air* be introduced. This is done in one of three ways. If two or more galleries run parallel, communications cut through them at intervals may produce a current of air: another way is to pierce a hole upwards from any part of a gallery: and another, to force air in by a pair of bellows.

Fig. 505.



The miners' bellows, or Haig's patent ventilator, is made of leather: it is cylindrical, with a circular wooden top and bottom. Its height and width are 13 inches each, and it holds one cubic foot of air. A man works it standing, with a staff screwed into an iron socket at the top, or sitting, by a short handle fixed to that socket. The air enters by a valve v, and is forced through a short nozzle n, $\frac{3}{4}$ of an inch in diameter. A cross bar c is fixed to the bottom with projecting ends for a man to stand upon to keep the bellows down while working. The air is conducted through tin tubes, $2\frac{1}{2}$ feet in length, $1\frac{1}{4}$ inch in diameter at one end and

tapered at the other to make it fit into the next. Flexible joints 1½ feet long, and

Fig. 506.

of the same diameters, made of leather with tin fixtures serve for connecting the tin pipes at the turnings of a gallery. The whole of these pipes are buried under ground in grooves; and a flexible joint is fixed in the mine at their extreme end.

(255). In sinking a shaft, a man can excavate and throw up the earth till he gets to a depth of 5 or 6 feet, after which he fills a basket with the loose earth, which two men at the top haul up.

In driving a gallery or branch from a shaft, one man picks, another fills, a third wheels, a fourth fills the basket, whilst two men haul it up at the top and spread it. When the length exceeds 60 feet, two wheelers are employed. When necessary one man works the bellows at the top.

In great shafts or galleries common intrenching tools may be used, but for excavating small shafts or branches, miner's pickaxes and shovels are the best tools; these are shorter and lighter than the former; in small galleries a solid

Fig. 507.

small iron rake is found useful: and to place the frames and sheeting, flat and pointed *push-picks* are employed.

Fig. 508.

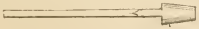


Fig. 509.

The buckets are cylindrical, 13 inches wide and high, and made of strong canvass stiffened at the top by 2½ inch rope inserted into a broad hem: by means of eye-

Fig. 510.

lets on each side, rope ears or handles are fixed to it. To raise it from the bottom, each of the two men at top has a rope made fast to one handle.

In low galleries and branches, where wheelbarrows cannot be used, small waggons or *miner's trucks*, resting on short cast-iron wheels, answer the same

Fig. 511.

purpose, a man pushing behind, assisted by another pulling with a rope in front, when the gallery is descending. If more than one truck is used in a gallery, recesses must be made in the sides to receive the empty one while the loaded one passes it. The miners generally descend or ascend in a shaft by rope ladders, but if none can be had, the miner sitting on the bight of a 2 inch rope is lowered down, one man holding each end of the rope.

Fig. 512.

When material or tools are wanted in the mine, they are let down by ropes or in a bucket. It is never allowed to throw them down.

In ordinary soil the great galleries and shaft proceed at the rate of 1 foot per hour, small galleries 1½ feet.

(256). The charge of powder is sometimes placed at the bottom of a shaft, sometimes at the extremity of a branch leading out of a gallery. In either case, a cubical recess, called the *chamber*, is cut at right angles to the shaft or branch, so that its body may be out of the direct line of it. The powder is carried in

Fig. 513.

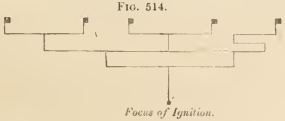
bags, containing 40 or 50 pounds each, and is poured into the chamber, or into a square box made for the purpose, and placed in the chamber if the ground is damp.

One pound of powder occupies 30 cubic inches.

A *powder hose*, or a tube, 1 inch in diameter, of strong linen filled with powder is placed in it, and reaches the point where the miner is to ignite it; generally it is protected by a wooden case, and fixed to the sides of the shaft by wooden pegs. More generally, Bickford's fuze is employed, which is a small waterproof flexible tube, containing powder covered all round with moist clay, and fired by a piece of portfire long enough to give the miner time to make his escape before the explosion: this method has the disadvantage of filling the galleries with smoke. The best method, when it is possible to employ it, is to fire the mine by means of a voltaic battery, or by Stratham's electric fuze. Previous to firing, it is necessary to *tamp* the mine, which is done by covering the chamber with a plank, closing the top with sods or sandbags, stopping the mouth in the same way, and placing struts between it and the opposite side of the gallery, filling the interval with sandbags, &c. The tamping is carried on in the gallery sufficiently far to prevent the mine from damaging it. If it is at the bottom of a shaft, the whole of it is tamped.

(257). When several mines are to be fired simultaneously, they are called *conjunct mines*, and the powder hoses or *saucissons* are brought together at the same point or *focus of ignition*, their respective lengths to the chambers being equal to

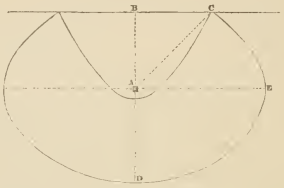
Fig. 514.



that of the furthest mine. The *focus of explosion* is the centre of the chamber itself.

(258). The effect produced by a mine depends upon the quantity of powder used, the depth at which it is placed, and the nature of the soil. If the charge is small, the explosion causes a mere spherical compression; but when the charge is sufficiently strong, the explosion raises the earth above, and forms a hollow circular opening or *crater*. An internal commotion is also produced, which may destroy shafts and galleries. The solid through which the commotion is felt is a kind of ellipsoid. The distances, AE, AD, to which this commotion extends are called *radii of rupture:* the radius, BC, of the opening is called the *radius of*

Fig. 515.



the crater. The line AC drawn from the charge to the edge of the crater is the *radius of explosion*, and the distance, AB, of the charge to the surface of the ground is the *line of least resistance*.

One-lined, two-lined, three-lined, &c. craters are those whose diameters are equal to once, twice, three times, &c., the line of least resistance.

Common mines are those forming two-lined craters.

Under-charged mines and *over-charged mines* are those produced with a quantity of powder less or greater than is necessary to produce a two-lined crater.

It has been found impossible to obtain craters of a radius greater than three times the line of least resistance, but the power of producing an interior effect of rupture has no limit. In a common mine, the major axis of the ellipsoid or horizontal radius of rupture is 1·7, and the minor axis or vertical radius is 1·3 of the line of least resistance. In a mine with the maximum crater, the horizontal axis is 4·36, the vertical 1·4, showing that by increasing the charge the effects below the mine are slightly increased, whilst the lateral effects are much greater.

(259). In order to find the quantity of powder necessary to produce craters of different diameters, express the line of least resistance in feet, cube it, and

for a one-lined crater multiply by ·033, two-lined ·1, three-lined ·21, four-lined ·45, five-lined 1, six-lined 1·75.

The product gives the charge in pounds. It corresponds to about 1½ pounds for every cubic yard contained in the crater.

The volume of the earth displaced in a common mine is generally considered as the frustrum of a cone, having for its height the line of least resistance, for radius of its larger end the same line, and for radius of its smaller end half that line; the solid contents are therefore $\frac{1}{12} l^3$. Allowing 1½ pounds for a cubic yard, this formula may serve to calculate the charge; the above method is more expeditious.

Over-charged mines, or *globes of compression*, are sometimes employed by the besieger, and less frequently by the besieged; they were recommended by Belidor towards the middle of last century. The line of resistance l, and the radius of crater r, being given in feet, the charge in pounds is $\left(\frac{(r-l)\cdot 9 + l}{10}\right)^3$.

For under-charged mines the charge would be $\left(\frac{l-(r-l)\cdot 9}{10}\right)^3$.

The radii of rupture in this case are the same as in common mines, but when the line of least resistance exceeds 10 feet, the horizontal radius of rupture $= \frac{C + 1500}{90}$, C being the charge in pounds.

A sufficient number of experiments, however, have not been made to justify us in placing implicit reliance on these formulæ.

It has been found that in doubling the charge we can dispense with the tamping, and that when the mine is excavated through different sorts of rocks, the charge found by the preceding rules must be multiplied by a co-efficient: thus in—

Light sand by 1·12, hard sand 1·25, wet sand 1·30, clay mixed with loam 1·55, fat earth 1·70, rock 2·25, good masonry or brickwork 2·25, old and good ditto 2·50, new and inferior 1·60, best masonry 2·90.

When exploding in open air, the resistance offered by the atmospheric pressure is nearly equal to the weight of a column of solid earth 12 feet thick.

(260). A *camouflet* is a small mine, charged with 10 or 12 pounds of powder, and formed in the wall of the enemy's gallery to blow in the earth.

(261). *Blasts* are small chambers or holes made in rock or masonry. The instruments required for making them are the jumper, the scraper, and the hammer. A miner holds the jumper, turning it round, whilst another strikes its head with the hammer, the scraper serves to clear the hole. The charge occupies one-third of the hole, straw stalks filled with powder are dipped in it, and the blast is tamped with pieces of rock or sand.

SECTION II.—Counter-Mines.

(262). The defensive mines, or counter-mines, are generally constructed at the same time as the fortress, and as a great number of systems have been proposed and employed without any one having such an advantage over the others as to be exclusively adopted, we shall confine ourselves to generalities and principles. Fig. 516 represents a disposition called the system of envelope galleries, fig. 517 the system of Gumpurtz and Lebrun, fig. 518 the system of Dufour; and many more exist, as those of Coulon, De Valliere, Belidor, Cormontaingne, Delorme, De Rugy, Monzé, Maresçot, &c. The system of Dufour, however, is considered, in the main, to be the best.

Fig. 516.

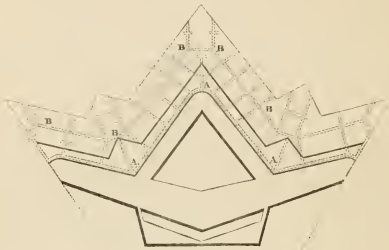


Fig. 517.

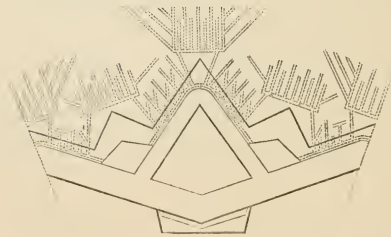
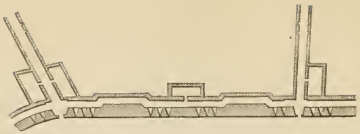


Fig. 518.

(263). A system of counter-mines generally consists of a *gallery* of *counterscarp*, or *magistral gallery*, A A A, close behind the revetment of the counterscarp, and of an *envelope gallery* B B B parallel to the former, and at a variable distance. The magistral and envelope galleries are connected by *galleries of communication*. From the envelope, *listeners* or listening *galleries* are pushed towards the country to meet the miner of the attack. Sometimes a gallery extends along the faces of the bastions and ravelins, especially where the breach is expected to be made, and is called an *escarp gallery*.

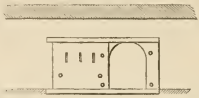
(264). The *magistral gallery* has sometimes been constructed under the banquette, or under the middle of the terreplein of the covered way, especially when the system of counter-mines has been prepared after the erection of the fortress; but it is preferable to establish it immediately behind the counterscarp, since besides being more economical, it is better lighted and ventilated. It is 6 feet wide, and from 7½ to 9 feet high. As it follows the counterscarp, which is thicker under the traverses, it is not exactly in a straight line. It is pierced with loopholes, both for ventilation and for the defence of the ditch. Small magazines for tools, wood, powder, &c., are constructed close to the galleries of communication. The entrances to the gallery from the ditch are formed of doors which can be bolted inside the gallery, so that the miners may isolate themselves should the

Fig. 519.



enemy succeed in reaching the ditch. The galleries of communication can also be isolated from the magistral, to prevent the enemy, who has entered the former, from occupying the latter, by means of sliding doors. These doors are loopholed,

Fig. 520.

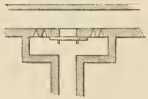


and can be fastened by means of iron pins passing through the door into the wall. The great objection made against counterscarp galleries is, that the enemy having possessed himself of them becomes master of the ditch.

(265). *Envelope galleries* are now seldom used, because presenting their sides to the globes of compression of the enemy, they are easily destroyed, and when lost serve as a basis of operations to the besieger's miner. They are only employed for small portions. Their dimensions are 4 feet wide and 6 feet high.

(266). *The galleries of communication* are of the same dimensions. They can be isolated from the envelope by sliding doors; a recess may be made at the junction, which serves as a depôt for tools; the door is defended from loopholes, or it may be barricaded by filling the whole recess with sandbags. The galleries

Fig. 521.



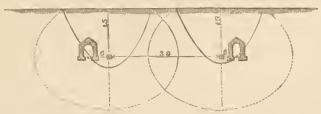
themselves can be closed by barricades of beams and sandbags; and grooves are prepared in both sides to enable the miners to slide the beams.

(267). *Listening galleries* are 4½ feet high and 3 feet wide, and must not exceed 45 yards in length, because the air becomes unfit for respiration beyond that distance. These galleries are made to enable the miners of the defence to

catch the sound of the blows of the enemy's tools, which he can hear if they are produced within a distance of 60 feet; and should he thus obtain a warning of his approach, he commences a small branch to take him in flank.

The listeners should not be more than 120 feet apart, so that the enemy cannot pass between them without being heard, and they should not be nearer than 48 feet, because with the usual line of resistance of 15 feet (270) two mines,

Fig. 522.



exploded in parallel listeners less distant, would overthrow the whole ground between them. At the distance of 48 feet, the effects of the radii of rupture will defend the interval very well.

In order to save time, openings are left at intervals of about 30 feet on the walls of the listeners, to facilitate the execution of the small branches; they are closed by thin walls, to prevent the earth from falling: grooves are also made at intervals of 8 or 10 feet, to facilitate the tamping by inserting beams, &c.

(268). Chambers of mine may be placed anywhere in the galleries themselves, or in the branches leading from them; but it is necessary that the position of those nearest to the covered way, intended to blow up the breaching and counter batteries, should be well determined, because their explosion might blow up the crest of the glacis, and expose the defenders. These chambers should be all placed in a plane inclined at 45° to the horizon, and passing at a distance of 24 feet from the crest of the glacis; and the small branches leading to them may be prepared beforehand.

At the point of juncture of two or more galleries, small vaulted chambers are usually constructed to facilitate the movements of the miners, and to serve as a depôt: they are circular, rectangular, &c., and covered with a dome or with

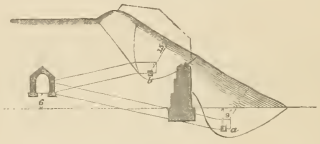
Fig. 523.

groined arches. An aperture in the arch in communication with the soil serves for ventilation. Similar chambers are also made in the middle of long galleries.

Fig. 524.

(269). The *escarp gallery*, when constructed, is 15 or 20 yards in rear of the escarp, and communicates with the interior retrenchment by a gallery in the capital, and two galleries parallel to the flanks. It serves as a base of a system of branches leading to mines prepared under the places where the breach and the enemy's lodgment are usually made. As the chamber *a* is about 3 feet below

Fig. 525.



the ditch, and chamber *b* at half the height of the revetment, the escarp gallery must be 2 yards above the bottom of the ditch, or at such a level as will not require too great a rise or descent to reach either mine, the maximum slope of a branch being 1 in 4. The escarp gallery may be connected with the magistral. It is true that, as the counterscarp gallery runs round the whole place, the miner may enter it at distant points to repair to the front of the attack by a circuitous way, but as it is prudent to barricade that gallery, to prevent a surprise, the miners would be obliged to cross the ditch, which is somewhat dangerous towards the latter part of the siege. A gallery of communication from the escarp gallery obviates this necessity, but it is liable to be filled with water, and its entrance by means of steps or ladders is inconvenient.

(270). The depth at which counter-mines should be constructed is now admitted to be from 4 to 6 yards. Before the discovery of the globes of compression it was recommended to have several stages of galleries, one above the

other, so as to blow up the ground several times in succession; but General Dufour has clearly proved that the *chambers of defensive mines should be in the same plane, at a depth of from* 4 *to* 6 *yards below the surface.* We give here his demonstration, translated in the "Aide-Mémoire."

Fig. 526.

Let now MN represent the water level, and B, B′ two mines placed as low as practicable, as regards the water level, which mines are supposed to be 30 feet below the surface of the ground; let C C′ C″ C‴ be the position of defensive mines, placed at half the depth of the first mines B, B′, and, like them, separated from each other by intervals equal to twice the line of their least resistance.

The besieger, in driving his gallery as low as possible, would place his mines as near as he deemed prudent to the defensive mines B and C, and load them as globes of compression, or surcharged mines. The solids of rupture of the defensive mines B and C are represented by dotted ellipses.

It will be observed that they keep off the besieger's third parallel, *equally distant from* the covered way, when the most advanced mine (C) of the upper system is carried forwards a few yards in front of the most advanced line of the lower system (B). The besieger's miner, then, endeavouring to give to his offensive mine (A) the greatest possible destructive action, would load it with 6000 or 7000lb. of powder, which would give to his horizontal radius of rupture a value equal to four times the line of least resistance, while the vertical radius of rupture would somewhat exceed that line.

But as in ordinary or common mines, the semi-axes major of the ellipsoid of rupture may be practically taken at about $1\frac{1}{2}$ times the line of least resistance, it follows from the figure that from B′ to O the distance is about $3\frac{1}{4}$ times the line

of least resistance; and that, consequently, the second mine B′, as well as the first mine B, would be destroyed by the same explosion.

With regard to the upper system of mines, there will be three of them within the circle of destruction of the mine A; the fourth C‴ being exterior to the ellipsoid of rupture, might be shaken but not destroyed. Therefore, by the explosion of the besieger's globe A, supposing all the defensive mines in the figure to be charged, the two lower ones, B B′, containing each 2700 lb. of powder, will occasion a loss of 5400 lb. to the besieged; while the four mines, C, C′ C″, C‴, containing only 337 lb., would entail a loss of 1001 lb. If, also, the extra tamping be taken into account, as well as the framing for the galleries, which is necessarily more considerable in two large than in three small ones, it will be found that the same explosion of the besieger will cause to the besieged a loss at least five times greater than what he would have suffered if his chambers had been placed at one half the same depth. Thus, therefore, under the inevitable losses which the besieged must necessarily experience, the defensive disposition C, C′, C″, C‴, appears to have obvious advantages over that offered by B, B′.

On the other hand, the mine C, from its downward or subvertical action, will prevent the besieger from passing below it, and equally prevent him from advancing beyond the line *b b′* as the mine B does. Both mines B and C would reach the enemy if he passed the line *b b′*, with this difference, however, that the mine C would employ, so to say, all its force, at an expense of 337lb. of powder to the besieged; while the other mine (B) expending a part of its effort in destroying the tenacity of the ground below, would cause an expenditure of eight times as much powder as mine C. It is from not having considered the effects of mines, in a subvertical or downward direction, that authors on this subject have fallen into the error now controverted, viz., "That the besieged ought always to occupy the lower position for his mines." The superior disposition will require, it is admitted, galleries pushed more in advance, and will cost, consequently, more, all other conditions remaining the same; but can an expense incurred at the time of the construction of the defensive mines be compared with that which results from a considerable consumption of powder, at a period of the siege when it is generally found to be deficient, and when no means can be resorted to for renewing the supply? And, besides, this prolongation of the galleries is not lost to the besieged, since the enemy, who generally is aware of the depth at which the mines are situated, would establish his third parallel at a distance from the rest of the glacis proportionably greater.

If to these advantages, which a system of mines situated at a moderate depth possesses, are added those of a readier mode of tamping, of greater salubrity, by getting rid of the water, and of economy in their first construction,— an economy due to the galleries being nearer the surface, which allows them to be constructed

in cuttings, instead of by the laborious process of tunnelling,—it will, it is conceived, be conceded that no doubt can exist of the advantages of the two systems, C, C′, C″, C‴, and B, B′. The upper system will therefore be selected, as situated at the most appropriate depth for the subterranean defence; and the principle will be assumed, that the chambers of defensive mines should be in the same plane, at a depth of from 12 to 18 feet below the surface. The position of the galleries which conduct to them, should be in another plane passing through the bottom of the ditch, at the foot of the counterscarp, and rising

Fig 527.

at such an inclination as to intersect the plane of the mines under the foot of the glacis. The plane of the galleries will therefore be favourably disposed for draining off the water and keeping them dry.

The mines, disposed as above explained, may be placed in the gallery when the latter is coincident with the planes of the mines; but generally the mines are reached by branches driven from the main galleries.

(271). When the besieger has constructed his third parallel, he commences his mining operations to discover the galleries of the besieged in order to blow them up, and to make safe of the ground below, before advancing further on the surface. The miner of the defence proceeds from his listening galleries to meet him. Both miners listen attentively for the sound of the pickaxe, so as to judge in which direction they must advance. Sometimes one of them, hearing his enemy approach, will stop working, to avoid giving him warning of his presence. When they arrive within four or five yards of each other, they employ camouflets; and when their branches meet, the miner who first perceived it pierces the earth with a borer, and fires a rocket through the hole to poison the air. As soon as the miner sees a borer, he must, at the moment it is withdrawn, fire a pistol through the hole, and endeavour to give his camouflet first.

If they meet they fight with arms, and try to seize each others galleries, and to find the chamber of mines, either with a view to take the powder, or to saturate it with water, or else to cut the wire that connects it with the battery. In his subterranean warfare the besieged fires common mines, only because he must economise his powder; and he avoids forming wide craters which the besieger can occupy.

(272). The besieger, on the contrary, will employ globes of compression. A first globe, at a depth of 7 or 8 yards, loaded with 4000 pounds of powder, will destroy the extremities of the galleries.

The crater is at once occupied with the flying sap, and from it advance is made further into the system of counter-mines, when a second globe is fired, then a third, and a fourth will generally blow in the counterscarp.

The defenders will oppose his advance, fire a few mines, delay him, &c. It is calculated that a system of counter-mines will arrest the besieger during forty days at least.

An engineer * lately observed that "countermines are as indispensable for a front attack as parapets and flanking fire, and that Vauban had, towards the latter part of his life, very properly advised Louis XIV., then in adversity, to construct them in all his fortresses." Bousmard also said: "Forty-two miners, properly employed, can double the duration of the resistance of a fortress, and counter-mines, whether constructed before hand or not, are the most powerful means of defence; the very means which, in case of a choice, must be preferred to all others, and for whose entire development everything must give way. They deserve the preference were it only on account of the support they give to other means of defence: artillery and musketry act most powerfully when the mines have uncovered the besieger; works of defence and fortifications are never so much dreaded by the besieger as when he knows they are countermined." Unfortunately the advice of Bousmard has not more prevailed than that of Vauban, and in France, from 1810 to 1840, not one gallery, nay, not a branch was constructed.

(273). We may here mention a method of attack by mining proposed by Gillot, a French engineer. After the construction of the third parallel, the approaches are suddenly stopped, and at night a flying sap is made between the parallel, and the crest of the glacis. In this trench the miners sink shafts 6 yards apart, to the depth of about 9 feet. This can be done in less than five hours, during which the besieged cannot alter his dispositions: 300 or 400lbs. of powder are placed at the bottom of these shafts, and all these mines being fired simultaneously, the counterscarp is insulated from the branches and their chambers.

A similar operation executed the following night in the covered way completely destroys the magistral galleries. Experience has not yet proved the value of this method: it can only be attempted when the garrison is demoralized by former attacks. It may cause to the besieger as severe a loss as the storming of the covered way; and in case of failure, the siege must be raised, or the attacks be resumed with the usual regularity.

(274). In order *to open a breach* by the mine, the charge should be placed

* Prevost de Vernois, De la Fortification depuis Vauban, 1861.

behind the escarp, in rear of the counterforts, from 2 to 3 feet above the

Fig. 528.

ditch (528), or 1 foot above the level of the water (529), and at a distance from

Fig. 529.

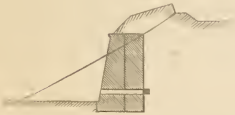


Fig. 530.

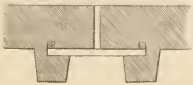
the terreplein, not less than twice the line of resistance, or the length from the charge to the face of the wall. Vauban placed the mines at a distance from the face of the escarp equal to $\frac{1}{2}$ or $\frac{1}{3}$ its height, near the tails of the counterforts.

Fig. 531.

He computed the charge at $\frac{1}{3}$ more than for a mine in common earth.

If, instead of making a breach, it is merely wanted to *destroy the escarp*, the charge is placed near the base of the wall, in the middle of each counterfort, in a

Fig. 532.



line with the back of the wall, and is equal to $\frac{1}{5}$ the cube of the thickness, the chambers being disposed at two-lined intervals. If the wall has no counterfort the charge may be placed at the back of the wall at two lined intervals, in which case it is $\frac{1}{2}\frac{1}{5}$ the cube of the thickness.

To *destroy a wall* standing alone, a barrel of powder is placed along it at its foot. If the thickness varies from 5 to 6 feet, the chamber must be placed under the foundations, and if the thickness averages from 9 to 12 feet, a branch is driven

at the level of the ditch; and the charge, computed at $\frac{1}{2}$ the cube of half the thickness, is placed in the centre of the wall at two lined intervals.

Fig. 533.

To *destroy a wall by blasting*, the hole is bored at 45° downwards; to the centre of the wall, and as much beyond it as will hold half the charge; the charge $= \frac{1}{4} l^3$, l being half the thickness The holes are at two-lined intervals, their diameters vary from $\frac{1}{30}$ to $\frac{1}{12}$ the thickness of the wall; frequently two holes instead of one, exactly opposite to each other, are bored from contrary sides of the wall, and unite in the centre in the form of a V or an X.

To destroy *galleries of countermines*, barrels of powder are placed along them ten feet apart, the total depth not exceeding 15 feet, and both ends are blocked up.

To destroy *powder magazines* or *bomb-proof* buildings, the charge is placed on the floor, at intervals equal to the line of least resistance; this is equal to the distance between the floor and the external surface of the building: the charge $= \frac{1}{8} l^3$. The door should be shut, and the windows blocked up with timbers. In a *casemate*, the charge should be nearer to the front than to the open end.

To destroy a *barrier gate*, the charge of powder, from 50 to 100 pounds, according to solidity, is attached, with a gimblet or spike, and fired with Bickford's fuze.

To destroy *bridges*, the piers are mined as for walls, but when there is no time, a trench is cut over the key of the arch, 18 inches deep; and 400 lbs. of powder are placed in it, and covered with timber and earth.

It has been found that in regular mining and blasting the charges must be increased by $\frac{1}{3}$, or even $\frac{1}{2}$, to obtain a violent instead of a moderate demolition.

CHAPTER XVII.

SYSTEMS OF VAUBAN.

VAUBAN, FIRST SYSTEM. (See 185.)

(275). The line of front, fixed at 360 yards, is a mean between the extreme limits which can be given to permanent fronts, with the relief adopted by Vauban. The minimum 300 is determined by the condition that the entrance of the postern on the middle of the curtain should be seen and defended by the musketry of the flank. The maximum 400 is obtained by the condition that the lines of defence should not exceed the effective range of musketry, (see 94.) Thus 360 is the length of the ordinary or mean front. The condition of seeing the postern

FIG. 534.

from the flanks is the basis of the alterations made to the relief when the length of the front is imposed upon us. Thus, if the front were only 240 yards and the relief 44 feet, there would be a dead angle before the curtain, and it would be so for every relief above 36 feet.

FIG. 535.

(276). The perpendicular varies from $\frac{1}{3}$th to $\frac{1}{4}$th.

The flanks are destined to defend the breach, and are counter-battered by the batteries established at the crowning of the covered way of the bastions: the besieger has a space equal to 40 yards—30, the width of the ditch, added to the

10 of the covered way. To have any chance of resisting these counter-batteries, the flanks should therefore not be less than 40 yards. In the hexagon, the perpendicular $\frac{1}{8}$th gives thus 54 yards. If it were made longer, the preponderance

Fig. 536.

of the flanks would increase, but the angle of the bastion would become too acute. This latter consideration renders it necessary to shorten it for the square and the pentagon, the angle of these polygons being smaller. All bastions are thus maintained of a proper size, but the flanks are shortened, and this is a drawback which is obviated by making the ditch somewhat narrower.

(277). The faces of the bastions are made equal to $\frac{1}{7}$ths of the front. Vauban in adopting this dimension, had in view the necessity of giving to the flanks a proper length, but the bastions are rather small, and cannot easily be defended in rear of the breach.

(278). The construction of the flanks by means of the circle described from the opposite salient as centre, gives to the angle of defence only 85° in order to defend at the same time the curtain and the face of the bastion.

(279). For ditches destined to contain water, Vauban increased the width from 30 to 36 yards. These wet ditches have the advantage of altogether preventing surprises, and of allowing a reduction in the amount of the garrison. The besieger has no longer an easy access to the breaches; a dam must be constructed, thereby limiting the front of the columns of assault. Two breaches only can be assaulted at one time, and the enemy cannot employ the ditch as a depôt. On the other side, the communications between the enceinte and outworks are difficult: they are established at the moment of need by means of bridges, which consume both time and labour, and after all constitute but a precarious communication, since the besieger will not fail to enfilade the ditches. As soon as the crowning of the covered way begins, the garrison can only communicate with the outworks by means of boats concealed in a little harbour reserved at the gorge of the ravelin. The defence is thus rendered less vigorous. In winter the water may freeze, and then wide cunettes must constantly be cut through the ice.

Dry ditches possess properties of an opposite character, the communications being safe and almost indestructible; sorties can be made, and the defence assume all its power. Wet ditches will therefore be preferred for small places, dry ones for fortresses well scarped and well garrisoned.

The best plan is to have ditches that can be filled and emptied at pleasure; in this case, they are kept full as long as the besieger cannot attack the outworks:

but when sorties become necessary, and when the possession of the outworks is to be disputed inch by inch, the water must disappear. The descent into the ditch is then easily submerged; the passage, too, is hindered by chasses, &c. If, however, a depth of water of 6 feet cannot be obtained, it is better to renounce the use of it, inasmuch as it then becomes an impediment to the defenders, without being an obstacle to the besiegers.

(280). The counterscarp of the main ditch is directed towards the shoulder-

FIG. 537.

angles of the bastions, to give full scope to the flanks; if it were to be kept parallel, a part of the defence of the flanks would be lost.

(281). The tenaille is traced on the lines of defence, and has a small relief, so as not to mask the artillery of the flanks. It can thus give a grazing fire on the terreplein of the ravelin, to prevent the besieger from occupying it, and also an oblique fire on the main ditch. It covers the revetment of the curtain and of the flanks, and gives in its rear a good space for the defenders to collect in safety. The passage of 8 yards at its extremities, called *trou de tenaille*, has the defect of enabling the besieger to breach the flank from the crest of the re-entering place of arms.

However small its relief may be, this work will always contrary to some extent the action of the flanks in the ditch, and give dead angles along these flanks.

The Caponier is merely intended to cover the defenders in passing across the ditch from one work to another.

(282). The *ravelins* constructed before Vauban's time, were very small; their object was to cover the gates of the place and to protect the covered way, yet the besiegers were obliged to carry them, either before or at the same time with the assault on the bastions, because the breach of the latter would have otherwise been exposed to reverse fire. Vauban increased the saliency and made of the ravelins a very important work, the long faces of which carry artillery, and render the advance on the capital of the bastion very difficult; when the polygon has many sides, the saliency of the ravelin is such that the enemy must take it before attempting an attack on the bastions. The interior of the ravelin of Vauban is sufficiently large to enable the defenders to construct some interior intrenchment therein.

The faces are directed to a point 10 yards from the shoulder angles of the bastions, to protect the flanks from the enemy's establishment on the crest of the glacis.

It must however be observed, that the escarp only of the shoulder angle is covered, and that the flanks are not: their command over the ravelin exposing them to reverse and enfilade. The ravelin has also the disadvantage of masking the fire of the curtain, and of being much exposed to enfilade.

The ditch has the same depth as the main one, and it leaves an opening called the "tron" of the ravelin, which enables the besieger to breach the face of the bastion with the counter batteries of the salient of the covered way, a serious inconvenience, which modern engineers have attempted to obviate.

(283). The *covered way* is, as its name implies, a path which was originally destined to receive small posts, to enable sentries to go their rounds and observe the enemy, to afford a cover to the men preparing for sorties, and also to them when afterwards retreating, so that the gates of the place might not be exposed. A banquette was subsequently erected, and the covered way became a defensive work, giving a strong grazing fire on the approaches. Vauban gave it a command of 8 feet and sometimes less, but its glacis does not mask sufficiently the masonry of the escarp, a great defect, which his successors corrected. He made it 10 yards broad only, to prevent the besieger from establishing his batteries in the terreplein, a width sufficient for the occupation and the free circulation of troops. The glacis has a gentle slope and cannot be destroyed, as would a mere parapet; the besieger must advance on a surface well defended, and has to excavate his crowning to obtain cover for his batteries, a labour of no small difficulty.

The re-entering places of arms are destined both to permit the garrison to form before making a sortie, and to flank the long branches of the glacis; for this latter reason Vauban made their angles of defence 100°. They form excellent posts, which permit the defence of the counterscarp to the last moment.

The sally ports are directed towards the crest of the salients of the covered way of the ravelin and bastion, to prevent the enemy from enfilading them. They are 4 yards wide, a width more than sufficient, because 5 men can march abreast through them; and at 80 paces per minute 400 men can file off through one port.

The object of the palisading is to increase the security of the defenders, and to prevent the enemy from jumping into the covered way; but it is far from adding strength to the defence, because the palisades are in the way of the muskets. Besides, the men cannot be close to the crest, and are more exposed.

In 1697, at the siege of Ath (some authors say in 1688, at the siege of Philipsburg), Vauban used the ricochet fire for the first time; and he afterwards threw up traverses along the covered way, about 30 yards apart, the distance of the flight of a ricocheting ball. Those established at the salient places of arms are placed on the rear of the faces of the ravelin and of the bastions, so as not to

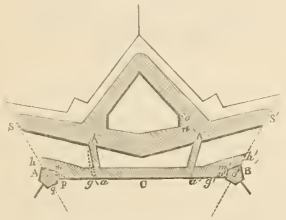
afford shelter to the enemy, and also to expose their terreplein to the view of the enceinte.

These traverses intercept most of the flank fire directed from the enceinte on the covered way, and prevent a rapid circulation, and since they oblige the defenders to pass through narrow crochets situated exactly under the crest of the glacis where the enemy comes, they render their retreat difficult. Vauban has therefore recommended a little trench to be dug during the siege, along the top of counterscarp on the rear of the traverses, into which the defenders can retire to avoid being seen by the enemy.

SECOND SYSTEM.

(284). The rapid progress of the art of attacking fortresses, and especially the discovery of ricochet fire, induced Vauban to modify his tracing. As the loss of the bastion was always followed by that of the town, he transformed the bastion into counterguards or outworks of the form of a lunette or a redan.

FIG. 538



o o' being the side of the polygon to be fortified = 280 yards, he erected at the angles bastioned towers A, B, in masonry, to flank the ditch of the enceinte. These towers contained two *Casemates*,* or subterranean vaults built bomb-proof; the first 6 feet above the level of the ditch: each casemate had two guns firing through embrasures on each flank, making altogether eight guns only for the ditch.

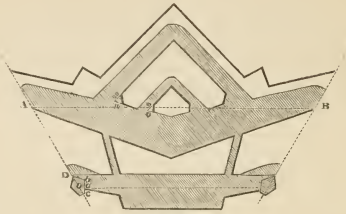
* Casemates, from the Spanish, 'casas-matas,' slaughter-houses; thus named because when these subterranean vaults were first employed it was supposed they would occasion great slaughter. The smoke generally disqualifies them from serving the artillery with any effect, but they constitute good shelter for men and ammunition during a siege.

THIRD SYSTEM.

(285). In his third system, the front A B being, as in the first, 360 yards, he gave an additional defence to the ditch by tracing a bastioned curtain with a perpendicular equal to 10 yards.

In this system the scarps were built of masonry to the level of the ground only, thereby giving a great exterior slope to the parapet. A berm of 10 feet was reserved at the top of this scarp.

FIG. 539.



TRACING THE SECOND SYSTEM.

(286). Let $o\,o'$ (Fig. 538) be the side of the polygon to be fortified, $o\,o' =$ 280 yards. At each angle is a tower of masonry: its demi-gorge measured on the side of the polygon is 10 yards long; its flanks are perpendicular to the curtain and measure 16 yards, $m\,n =$ 12, and $n\,p =$ 4; its salient angle $=$ 90°.

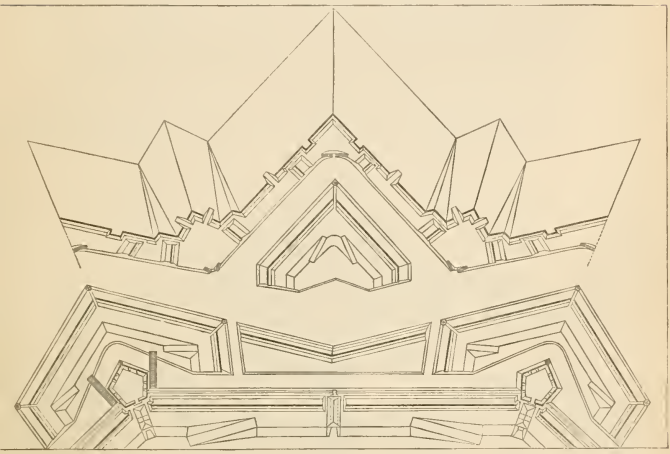
The salients s, s' of the bastions transformed into counterguards are at the distance of $\frac{2}{3}$ths of the front $o\,o'$ from the salient angles of the towers; the faces are directed on the flanking angles $n\,n'$ of the enceinte: the shoulder angles are determined by circles described from the salients s, s', as centres and radii S g', S' g, the points g and g' bisecting the semi-curtains C o, C o'; the flanks are directed to a, a' taken at 2 yards from g, g'. The extremities of those flanks are obtained by joining $m\,h'$ and $m'\,h$; the intersection of $h\,m'$ and $k\,a$ limits the flank of the left counterguard, that of $h'\,m$ and $k'\,a'$ the flank of the right. This construction prevents the besieger, when arrived in one counterguard from getting a view of the other, and gives the flank of a tower a sight of the salient of the next. The demi-gorges of the countergnards coincide with the lines $m\,h'$, $m'\,h$, as far as 20 yards from the flanks, and become tangent to circles of 14 yards radii, described from the salients of the towers as centres.

The tenaille is traced on the lines of defence; its rear is on the line that joins the extremities of the flanks, and its profiles are parallel and at 10 yards from these flanks. The ditch in front of the counterguards is traced as in the first system, 30 yards wide at the salient, and its counterscarp is directed on k, k'. The capital of ravelin is 90 yards, the faces are directed to 20 yards, from the shoulder angles k, k', and they have flanks determined by taking off 20 yards on the faces and 14 on the demi-gorges. The rest of the front is traced as in the first system.

The commands of this system above the ground are for towers 24 feet, counterguards and enceinte 22 feet, ravelin 18 feet, glacis 8 feet, ditch 20 feet deep.

FIG. 540.

Landau.



TRACING THE THIRD SYSTEM.

(287). To trace the third system, Vauban took the line of front A B (Fig. 539) equal to 360 yards, and constructed a front of his first system on it, with these differences, that the faces of the bastion were a third of the front, that the capital of the ravelin had 110 yards, and its faces were directed at 20 yards from the shoulder

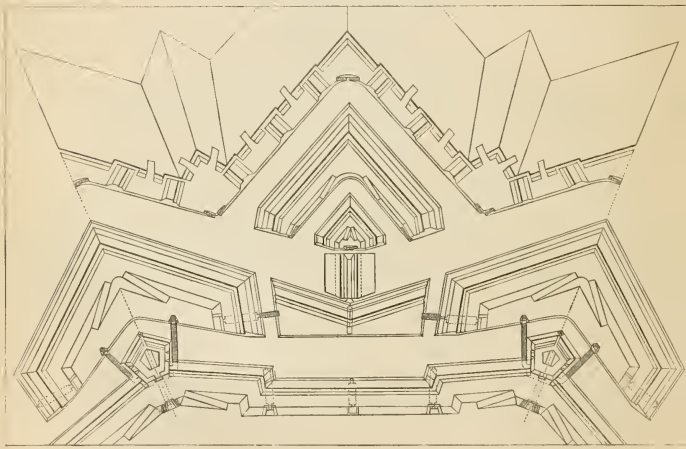
angle, and that the capital of its redoubt was 45 yards. The flanks of the ravelin were traced as in the second system, and those of the redoubt were parallel to them, and equal to $\frac{3}{4}$ths of their length. The ditch of reduit was 10 yards wide.

The old curtain being produced, till it cuts the radii of the polygon, the intersections determine the salients of the towers: parallel to it, and 18 yards in rear is the interior side, on which a bastioned front is constructed with a perpendicular of 10 yards, and with flanks traced on the prolongation of the flanks of the counterguards. To trace the towers 14 yards *o a* are taken on the interior side, and at that point a perpendicular is drawn 12 yards from *a* to *b*, and 8 yards from *a* to *c*. The face is formed by joining D *b*. The ditch of the tower is 14 yards wide at the salient, and the demi-gorge of the counterguard after following the old curtain for 20 yards, becomes tangent to the circle of 14 yards. The tenaille traced as on the first system on the lines of defence has its gorge on the old curtain, and its profiles are parallel to and 10 yards from the flanks.

The commands were:—towers 22 feet, counterguards and enceinte 20 feet, reduit in ravelin 17 feet, ravelin 14 feet, glacis 8 feet, ditch 15 feet deep.

Fig. 541.

New Brissach.



In these two systems, the bastioned towers contain casemates separated by a strong pillar of masonry. Access is given to these casemates by posterns that cover the staircases to the platforms at the gorges of the towers; the same posterns also lead to the ditch and to small bridges that serve as communications between the enceinte and the counterguards. Similar bridges lead from the counterguards to the tenailles, and the tenailles are also reached from the ditch by means of ramps.

The top or platform of the towers, consists of a mass of earth rammed down over the casemates: it is provided with a parapet of bricks 2 yards thick, with two embrasures on each flank, and banquettes along the faces. In the towers of the third system, this parapet is also constructed along the gorge, in order to convert the platform into a reduit; and a splinter-proof traverse is placed at the centre.

The small flanks of the third system, contain a casemate for two guns each, at the same level as those of the towers; they are entered by posterns established in the curtain.

In the third system the revetments of the ravelins and counterguards are not carried up higher than the level of the ground, very likely for the sake of economy. The exterior slopes have thus a great size, and a berm of 10 feet runs along these works between the top of the revetment and the foot of the exterior slope.

Section and Profiles of the Third System.

FIG. 542.

FIG. 543.

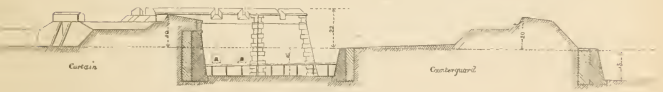
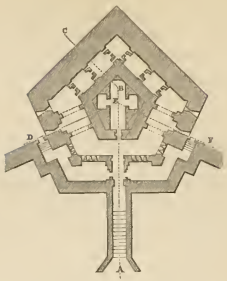


FIG. 544.

Fig. 545.



Tower Bastion.

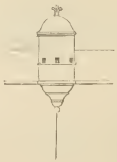
Fig. 546.

Fig. 547

The revetments of the enceinte and of the reduit of ravelin are raised up to the level of the exterior crest of the parapet; the thickness and slope are the same as for the first system. They are called *full* revetments, to distinguish them from those of the ravelins and counterguards, which are called *demi-revetments*. In full revetments, the part of the wall above the level of the rampart is only 3 feet thick, and has no slope.

In these systems as well as in the first, Vauban has constructed some stone sentry-boxes or turrets called *guerites*, at the top of the revetment of the salient

Fig. 548.



angles. They project over the ditch, so that sentries placed in them command

the ditch through loopholes without being exposed to musketry fire. It was formerly the fashion to ornament them; but this has been abandoned because it marked the position of the salients, and facilitated the taking up of the prolongation of the faces.

PROPERTIES OF THESE SYSTEMS.

(288). The advantage of these systems are, that the enceinte of the place cannot be breached by the batteries established before the salient of the ravelin, and the enemy has first to occupy the counterguards; and as these are commanded within a short range by the enceinte, he will find it most difficult to construct breaching batteries in them. The towers protect the enceinte against enfilade, and afford great security to the guns in the casemates against vertical and direct fire. The defects are, that the towers being made of masonry, their platforms are much exposed to the effects of splinters, more so in the second than in the third system. In this system the towers can serve as reduits, and they will flank the terreplein of the enceinte. The flanks of one tower cannot efficiently defend the faces of the other two, owing to the great projection of the counterscarps of their ditches. But, what is worse still, the towers can be so injured before the counterguards are taken as to become useless in preventing the besieger from erecting batteries against the body of the place. The flanks of the counterguards are too small for the defence of the main ditch; the ditch of the enceinte is only flanked by eight guns in the second system; in the third there are sixteen guns, but the small flanks being in the prolongation of those of the counterguards are exposed to enfilade. The ravelins with flanks have the inconvenience of exposing the shoulder angles of the counterguards, and of enabling the besieger to breach the enceinte from the lodgment of the re-entering place of arms through the openings of the tenaille; this defect is somewhat less in the third system, where the greater saliency of the ravelin will besides prevent the enemy from forming a lodgment at the salient of the covered way of the bastion, before he has carried that ravelin; it will also oblige the besieger to open his trenches at a greater distance: the reduit will prevent him from forming lodgments in the ravelin. In weighing the advantages and defects, it is very doubtful whether the defence gains anything; and as the expenditure in masonry is doubled, these systems have not been employed since Vauban's time.

THEIR ATTACK.

(289). The methods of attack for the second and third systems are the same. For polygons of fewer than eight sides, the process is the same as for the first system, until the counterguards are taken (203): for higher polygons the saliency

of the ravelins is sufficient to enable the men to see at reverse the crowning of the covered way of the counterguards; the besieger will therefore be obliged to carry two ravelins, and to advance on the counterguard situated between them.

As regards the construction of the trench cavaliers against the ravelins, which is effected on the thirteenth night of the siege, all that has been said (203) may be repeated. The crowning begins at the same time, and the next night it is pushed on as far as the first traverse; the counter batteries (1, 1) against the adjacent counterguards, and the breaching batteries (2, 2) against the central work are begun, and also the trench cavaliers against the same work and the re-entering places of arms.

On the fifteenth day these cavaliers are completed, and batteries of light mortars (3, 3) are prepared against the places of arms and the counterguard: the crowning of the covered way of the ravelins reaches the second traverse, when the breaching batteries (4, 4) with the descents are undertaken. On the nineteenth day the breaches of ravelin and their descents are ready, and the besieger takes the ravelins and crowns the breaches.

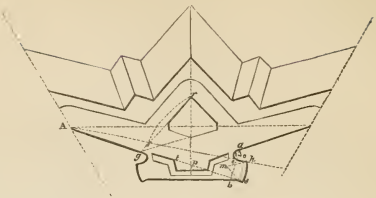
FIG. 549.

The redults of ravelins are taken on the twenty-third night. The lodgments are first enlarged to receive a few mortars (5, 5) for firing stones at the garrison; then breaching batteries (6, 6) are constructed in front; and a descent gives access to the ditch if the besieger does not blow in the counterscarp. The same night, the glacis of the re-entering places of arms, and the covered way of the counterguard, are completely organized, the former into a battery (7, 7) to breach the body of the place through the opening of the tenaille, the latter into counter-batteries (8, 8) against the flanks of the collateral counterguards, the passage along the ditch of the ravelin advancing as far as the main ditch. On the twenty-fourth day, under the protection of the counter-batteries (8), the passage of the ditch reaches the breach of the counterguard, and the assault is given. The lodgment is made, and from its extremities the besieger runs a sap through the parapet in order to drive off by musketry fire the defenders of the tenaille, whilst another sap is pushed on between the tenaille and the flank of the counterguard. The following night, the breaching batteries (9, 9) are completed in the redults, which together with the batteries of the ravelin and of the places of arms, enlarge the breaches of the enceinte; at the same time, the besieger erects in the counterguards some batteries (10, 10) to counter-batter the enceinte, and more especially the casemated flanks having view on the breaches and the tower, and sinks shafts in the lodgment, to run galleries to the counterscarp, opposite the shoulder angles of the tower. These galleries will permit the lodgment of chambers of mine, which, by their explosions, will throw a sufficient quantity of rubbish to mask the embrasures of the casemates. The batteries are ready on the twenty-ninth, and the mines on the thirty-first only; in the meanwhile, the passage of the ditch has entered the ditch of the enceinte in full sap, and reached the foot of the breach. On the thirty-second night, the mines are sprung, and the assault is given at daybreak.

FIRST SYSTEM OF VAUBAN.

(290). To complete all that relates to Vauban's systems, we may allude to the first of his tracings, which differs from the front which we have given before. It is only step by step that Vauban improved this tracing; and the front called his first system, contains all the improvements which he successively carried out. The enceinte was first drawn as explained; and in order to conceal some artillery, and keep it intact on the flank for the defence of the breach, he gave an orillon to the flank. An orillon may be defined to be a prolongation of the face of a bastion beyond the flank. It was used by the engineers of his time, who found it advantageous to protect the several flanks of their bastions, but the expense of the masonry which it necessitates is out of proportion to the advantages gained

Fig. 550.



when no such flanks exist: the gun to be concealed may be struck at reverse by ricochet, or a shell may destroy it. To trace this orillon, Vauban takes the third part $a\,c$, of the flank for gorge: through the middle l, he erects a perpendicular $l\,o$, and from the extremity a of the face a perpendicular $a\,o$, to it; the intersection of these perpendiculars gives the radius $a\,o$, which serves to describe the orillon from centre o. From the salient A of the collateral bastion, the lines $A\,c$, $A\,b$ are drawn to the interior extremity of the orillon, and of the original flank; on these lines produced, $c\,h$ and $b\,d$ are taken equal to 10 yards, the curtain having thus a *brisure* $b\,d$, and the wall $c\,h$, forming the *reverse* of the orillon. Instead of tracing the retired flank along $h\,d$, he described an equilateral triangle on that line, and from the vertex m as centre, and radius $m\,h$, he traced the curved flank.

The first tenaille of Vauban was also different from the tracing he adopted afterwards: it had faces, flanks, and curtain. The faces terminated at 8 yards from the orillons, their length, $s\,t$, being equal to half the line of defence, $s\,p$. The flanks were parallel to the original straight flanks of the enceinte. The curtain was traced parallel to, and at 22 yards from the curtains of the enceinte. The thickness of the faces and flanks was 15 yards, but that of the curtain was only 12 yards, in order to leave 10 yards passage between its gorge and the enceinte.

This tracing was soon set aside, because it exposed the defenders to reverse and slanting fire from the salient of the covered way of the bastion, thereby rendering the tenaille useless for the defence of the ditch.

The demi-lune was traced by describing a circle with the flanking angle b, as centre, and radius $b\,g$: the intersection r, of that circle with the perpendicular fixed the position of the salient, and the faces were directed to the extremities a, g, of the faces. It had flanks traced like those of the second and third systems. These flanks were destined to receive four guns each to fire on the breach of the bastion; but we have seen that the saliency of this ravelin was not sufficient to

prevent the besieger from attacking the bastion before the ravelin, and that the flanks had the defect of exposing the shoulder angle of the bastion and their flanks to be breached from the counter-batteries of the salient of the covered way. The figs. 551, 552 represent the profiles of this first system.

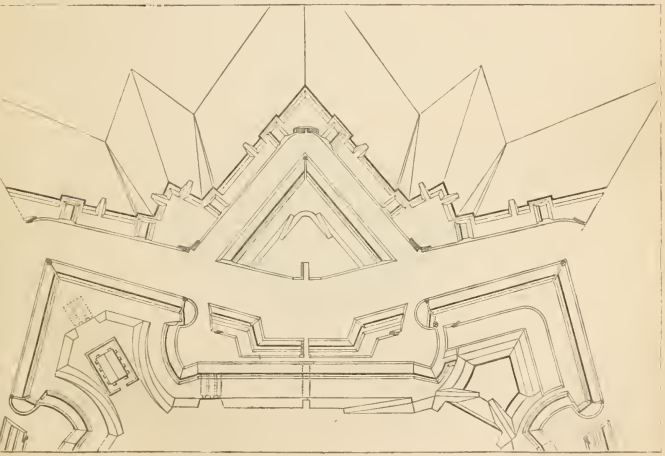
Fig. 551.

Fig. 552.

The duration of the siege of a place of this sort has been estimated at nineteen days.

Fig. 553.

Sarrelouis.



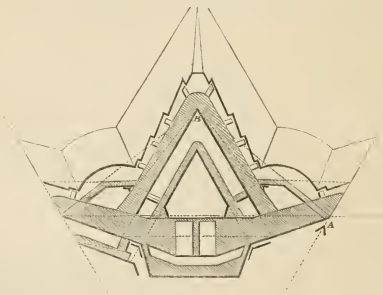
CHAPTER XVIII.

MODERN SYSTEM.

(291). Cormontaingne, a disciple of Vauban (471), is the author of a system which was first applied in 1728 and 1735 to the forts Moselle and Bellecroix, at Metz. After having received some modifications from modern engineers, it has become known in this country under the name of Modern Front.

Supposing the line of front = 360 yards, the perpendiculars are fixed, as in Vauban, at $\frac{1}{2}$th, $\frac{1}{3}$th, $\frac{1}{6}$th. The faces of the bastion are $\frac{1}{3}$rd of the front, 120 yards; the flanks are drawn perpendicularly to the lines of defence.

Fig. 554.



The re-entering angle of the tenaille in Vauban could not be seen from the flanks; to obviate this, a curtain of tenaille is traced parallel to the enceinte at 26 yards; the thickness remains 16 yards, and the extreme profiles are at 5 yards from the flanks; the counterscarp of the main ditch is tangent to circles described

from the salients with a radius of 30 yards, and directed on the shoulder-angles of the crests of the bastions.

In order to prevent the besieger from crowning the covered way of the bastions at the same time as that of the ravelin, Vauban in his last tracings gave a greater saliency to the ravelin. Cormontaingne took its capital, equal to $\frac{1}{7}$ths of the front. Now, 34 yards are taken off from the shoulder-angle of the bastions, along the faces: an equilateral triangle described on this line, gives the ravelin. The ditch is 20 yards wide, and 6 feet less in depth than the main ditch. The ravelin is 20 yards thick. Its great saliency, which increases with the opening of the angles of the polygon, obliges the besieger to take it before crowning the covered way of the bastions, and its reduced thickness prevents him from establishing batteries on the terreplein to breach the redoubt.

Vauban usually placed a redoubt in the ravelin; instead of constructing it with palisades, Cormontaingne gave it a scarp and a ditch. The face of this redoubt is drawn parallel to that of the ravelin from the shoulder-angle of the crest of the bastion. Its ditch is 10 yards wide, its depth is 18 feet less than that of the main ditch, to prevent the besieger from attacking the ravelin at the gorge. Its gorge is obtained by bisecting the thickness of the ravelin at its extremities, and joining the points of bisection. It is therefore parallel to the curtain, and the staircases cannot be seen from any part of the covered way.

The flanks of the redoubt are traced by marking off 20 yards on each face from the point where they meet the gorge, setting 16 yards off on the gorge, and joining. These redoubts must be carried too, before assaulting the bastions, since their flanks (18 yards long, and armed with 4 guns) can give a slanting and reverse fire on the breaches of the enceinte.

The caponier remains as in Vauban.

The covered way is also of the same width, 10 yards. The re-entering places of arms are larger, and contain a redoubt, which renders the attack by vive force impossible.

This redoubt is traced by bisecting the re-entering angle of the counterscarp, and joining the flanked angles of the bastion and ravelin together; the line A B thus obtained gives the counterscarp of one face of the redoubt, the other is drawn from the salient places of arms before the bastion. The scarp is parallel, and at 5 yards distance. The parapet of this face has a flank of 6 yards, to give a fire on the breach of the ravelin; in order to mask the staircase at the gorge, the ditch of the ravelin is enlarged by tracing the counterscarp on the line that joins the extremity of this flank to the salient angle of the ravelin.

The ditch of the face towards the bastion is not flanked—a great disadvantage. In Vauban's system, the besieger could establish batteries in the covered way of the re-entering place of arms, and breach the curtain through the space inter-

vening between the tenaille and the flanks, called *Trous des Tenailles*, thereby obliging the defender to give a great extent to the interior retrenchments constructed to prolong the resistance after the assault on the bastion. With this tracing, the trous des tenailles are masked.

The strength of the redoubts obliges the besieger to advance carefully to the crowning of the covered way of the bastion, and compels him to run a fourth parallel across the slope of the glacis.

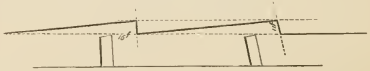
The crest of the re-entering place of arms itself is described from the re-entering angle of the counterscarp as a centre, with a radius of 65 yards.

The crest of the salient place of arms is cut off perpendicularly to the capital, to give a banquette of 6 yards, in order to obtain a direct fire on the approach.

The glacis is also 50 yards wide.

The traverses of the re-entering places of arms are traced, as in Vauban, 6 yards thick; along the faces there are two more traverses, 3 yards thick: the crochets are traced in Cremaillêre to prevent the besieger from finding shelter in

Fig. 555.



them, as was the case with the crochets of Vauban, but they are exposed to enfilade. The passages are still 9 feet in the clear.

To command the approaches when the ground presents hollows, as well as to form traverses or parados to protect the houses or other buildings in the rear, *Cavaliers*, or works with a great relief, have been employed, in any part of the enceinte. They are generally constructed of earth, and so organized as to form an interior retrenchment.

When such a cavalier is to be constructed in a bastion, its faces are traced parallel to those of the bastion, and 34 yards within them: the ditch is 10 yards wide. The crests of its faces are parallel to, and at 10 yards from the cordon, and on the flanks at 34 yards from those of the bastion.

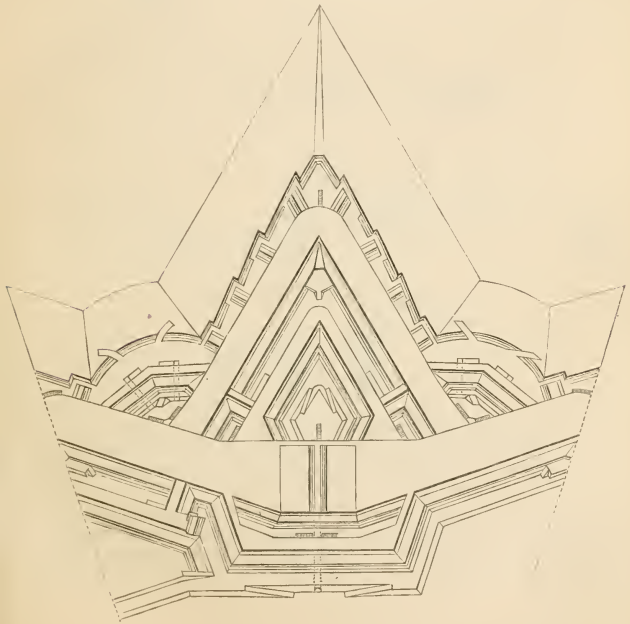
The length of these is fixed by tracing the base of the exterior slope at 10 yards from the crest, and making it 28 yards long.

To transform it into an intrenchment, a *Coupure* is made on the face of the bastion at the point where the breaches can be made. Its counterscarp is drawn perpendicularly to the face of the bastion from the point where they are met by the faces of the ravelin produced.

Its scarp is parallel to, and at 10 yards from it; its crest at 7 yards. To flank the ditch of the cavalier, a traverse is erected on the rear of the coupure, perpendicularly to the face of the cavalier, and 8 yards in the rear of the scarp of the coupure. Its crest is at 7 yards in rear of the cordon, and is 12 yards long. The length of the parapet of the coupure and that of its traverse are limited by a line drawn from the extremity of the crest to the corner of the countescarp of the coupure—a method which conceals the staircase of the coupure from the terreplein of the bastion, and insures a safe retreat.

A coupure is also made in the face of the ravelin: its countescarp is determined by a perpendicular drawn from the extremity of the face of the reduit of Re-entering Place of Arms. Its ditch is 5 yards wide.

FIG. 556



x 2

(292). The commands and reliefs of the modern system are not absolutely fixed, every author adopting different dimensions.

We give here those generally adopted in England, and refer for the discussion of this subject to Chapters XX. and XXII.

The line A B represents the level of the ground.

FIG. 557.

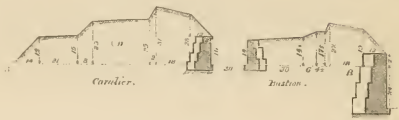


FIG. 558.

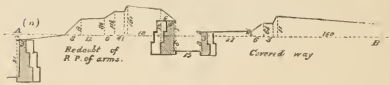


FIG. 559.

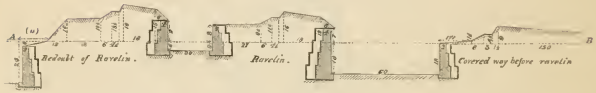


FIG. 560.

(293). The revetments are countersloping (See Section IV., Chapter XX.) The thickness at the top is marked in the profiles. That at the bottom is equal to $\frac{1}{3}$ of the height of the masonry. The counterforts have a length equal to the mean thickness of the walls.

The bottom of the ditch of ravelin is 6 feet above that of the main ditch, a disposition which enables the face of the bastion to defend it better, whilst the step formed at the retaining wall between both ditches presents a serious obstacle to the enemy advancing by sap along the ravelin towards the main ditch. The

ditch of the redoubt of the ravelin is 18 feet above the main one, to secure the ravelin from being attacked at the gorge.

The tron of the ravelin is generally closed by a traverse constructed in the ditch of the ravelin; it is high enough to protect the scarp of the bastion, and its exterior slope forms a kind of glacis swept by the fire of the bastion.

Its crest is parallel to the counterscarp, and 28 feet from it.

It joins on one side the redoubt of re-entering place of arms, and is separated on the other by a passage, so that the enemy cannot make use of the traverse to escalade the ravelin; this passage may be covered by a small traverse in rear.

A postern forms, as in Vauban, a communication from the interior of the place through the curtain with the main ditch. It also passes through the tenaille. Staircases are placed at the gorge of the redoubt of the ravelin, of the tenaille, of the salient and re-entering places of arms.

A ramp 12 yards long and 3 yards wide leads from the ditch of the redoubt of the re-entering place of arms to the covered way.

The terreplein of the redoubt communicates with its ditch by means of a postern 6 feet wide.

Ramps 20 yards long and 4 wide lead from the ravelin to the ditch of its redoubt, and a staircase communicates from this ditch with the terreplein of the coupure.

Posterns through the middle of the redoubt of the ravelin lead from its terreplein to its ditch.

The usual ramps are constructed along the ramparts, barbettes also are erected at the salients of bastions, ravelins, and redoubts of ravelins.

Staircases lead from the rampart of the enceinte to the ditch of the coupure, and from thence a ramp ascends to the face of the bastion.

Two ramps also lead from the rampart of the bastion to the terreplein of the cavalier.

The sally-ports of the re-entering places of arms are of a curved outline, to prevent enfilade.

As in Vauban, and all other systems, a *Cunette*, or diminutive ditch in the middle of the main ditch, serves to drain it.

(294). Although differing but slightly from the modern system, the method of Cormontaingne may be given in a few lines, to show the link that connects the tracing of Vauban with that which has just been explained.

The front $= 360$ yards; the perpendicular $\frac{1}{8}$, $\frac{1}{7}$ or $\frac{1}{6}$; the faces of bastion $\frac{1}{3}$; the flanks are perpendicular to the lines of defence.

If $b\ c$, $c\ c'$, $c\ b'$, represent the crests of the parapet of the enceinte, Cormontaingne considered the part $d\ c$ of the flank as useless, because the direct shots from it will be stopped by the opposite shoulder angle, and he proposed to bring forward

Fig. 561.

the crest of curtains to *d d'*, and the magistral to D D'. It may cause a slight saving of masonry, but it is not an improvement, since the part *d e* can defend the ditch and the covered way, although it cannot see the foot of the escarp.

The ditch is 30 yards wide at the salients, and its counterscarp is directed on points of the flanks at 5 yards from the shoulder angles.

Fig. 562.

The faces of the ravelin are directed to points on the faces of the bastions 20 yards from their shoulders, and the flanked angle is determined by the intersection with the perpendicular of an arc described from one of these points as centre, and at the distance of the shoulder angle of the opposite bastion as radius. The faces are 15 yards thick; the ditch of the redoubt is 10 yards wide; and the faces, parallel to those of the ravelin, terminate at 18 yards from the counterscarp of the main ditch; its flanks are perpendicular to the line of front, and its gorge is traced by joining points at 20 yards from the capital, measured on each side of the re-entering angle of the counterscarp.

The ditch of ravelin is 20 yards wide: the covered way 10 yards.

The faces of the re-entering place of arms are inclined at 100° to the long branches, as in Vauban, and the capital = 72 yards.

The redoubt in the re-entering place of arms is traced by giving 40 yards to the demi-gorge, measured on the counterscarp, directing one face to the salient of the covered way of bastion, and making the other face equally inclined on the capital.

The interior faces have a flank of 6 yards, made by thickening the parapet. The ditch is 6 yards wide.

The traverses remain as in Vauban, with this difference, that they are only 9 feet thick, except those that close the re-entering places of arms, which are 18 feet; the crochets are traced "*en cremaillere*."

The commands and reliefs are such that the line of fire from the parapet of the enceinte to the foot of the glacis passes 3 feet above the palisades of the covered way. The salient of faces is kept 1 foot higher than the extremities, in order to resist ricochet; but the effect is so insignificant that the improvement has not been adopted in the former system.

The commands of this system are small. Cormontaingne trusted to the difficulty which the besieger would meet in ascertaining the prolongation of the faces, but he overlooked the necessity of a commanding fire on the works of the attack, behind which the besieger is less exposed when the commands are less.

Command of the enceinte, 18, and at salient of bastion, 19
„ of redoubt of ravelin, 16, and at salient, 17
„ of ravelin, 14, and at salient, 15
„ of redoubt in re-entering place of arms, 12
„ of tenaille, 2
„ of covered way, 8
Depth of main ditch and ditch of ravelin, 22
„ of ditch of reduit of ravelin, 7
„ „ of re-entering place of arms, 8
Height of the escarp of enceinte, 30
„ of ravelin, 28
„ of redoubt of ravelin, 15
„ of re-entering place of arms, 14

The communications are the same as in the modern system.

In the profiles *a b* represents the level of the ground.

FIG. 563.

Fig. 564.

Fig. 565.

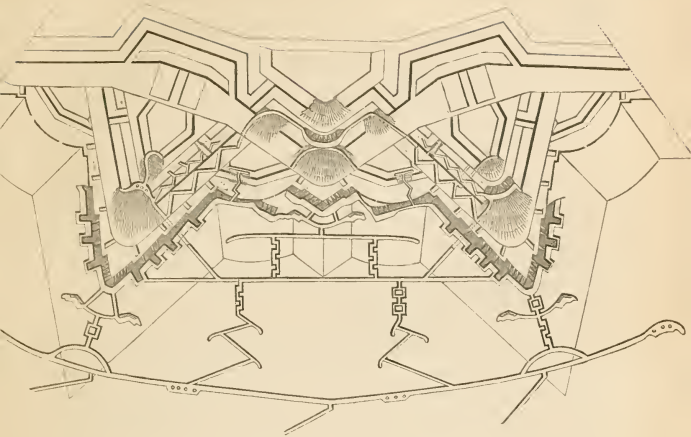
Owing to the great saliency of the ravelins of the modern system, the besieger is obliged to direct his attack on two ravelins, and the bastion between them. The process of attack remains the same as for a fortress of Vauban, until the completion of the third parallel, when it becomes impossible to advance on the capital of the bastion before having occupied the salient places of arms, and part of the covered way of the ravelins. When, however, this crowning is completed, two systems of zig-zags or of double saps are carried onwards from the third parallel, and the *fourth parallel* is constructed at the foot of the glacis of the bastion, and rests at each extremity on the trench cavaliers. In order to gain as much ground as possible, it is traced of a convex form towards the place, or at least in straight line, and is excavated by six saps, viz., tho two double saps of the advance, turning right and left, and a sap striking out from each covered way of the ravelins.

The ravelins are next taken; breaching and counter batteries are constructed as before; the descent into the ditch is prepared; the breach is made, and the ravelins are taken possession of, either by assault, or by means of a lodgment. The besieger may then advance by sap on the terreplein of the ravelins against their coupures.

The advance from the fourth parallel can now proceed, but when the ravelins are very salient, as in polygons of many sides, there is still a large space between that parallel and the salient place of arms of the bastion of attack; it is then necessary to construct a demi-parallel at half-way.

The redoubts of a ravelin are at the same time attacked, and various methods of doing this have been proposed. A battery of sandbags is erected near the counterscarp to breach the salient of the redoubt and counterbatter the faces of the bastions that defend its ditch. It is a difficult operation, especially when there are coupures in the ravelins, and these should first be taken: the besieger therefore advances by a narrow zig-zag sap, cut through the parapet of the

Fig. 566.



ravelin, and connected with small trenches across the terreplein, destined to place marksmen for subduing the fire from the redoubts. The sap having proceeded as far as the counterscarp of the coupure, the miners sink a shaft, pierce through both the counterscarp and the escarp, and blow down both revetments, so that the besieger can form his lodgment in the coupures. Despite the success of this operation, the arming of the batteries against the redoubt is a long and difficult task, and it is not to be done if the defence is still vigorous. It is better to breach the redoubt from the batteries established at the salient of the covered way of the ravelin, whence fire is directed through an opening made right through the whole thickness of the rampart of a face of the ravelin, either by artillery or by mine. Most engineers, however, recommend the use of the mine exclusively, more especially if the defence can still bring guns to bear on the ditch of the redoubt. The lodgement at the salient of the ravelin being converted into a battery to counterbatter those guns, a zig-zag trench is carried through the ditch of ravelin to permit the miner to reach the escarp, when two galleries, a great and a common one, are driven through the ravelin up to the ditch of the redoubt. The common gallery pierces through the counterscarp, then the escarp of the redoubt, and a mine blowing down both revetments makes a breach; the great gallery is

then opened through the counterscarp, and serves as a passage to the storming party.

The redoubt being taken in this manner, the defenders are obliged to abandon the coupures of the ravelin, and the besieger at once forms his lodgment in them, by advancing across the ditch of redoubt, and blowing down the revetments.

The advance from the fourth parallel, or from the demi-parallel towards the salient place of arms of the bastion continues, and the crowning of the covered way of the ravelin is also extended.

If the defenders have not abandoned the covered way of the bastion, it may be necessary to erect trench cavaliers as for the ravelin, and it is only when the covered way and its reduit are altogether left by the garrison that the crowning is carried all round the crest of the glacis. The breaching and counter batteries against the bastion are then constructed. In general, when the redoubt of ravelin is taken, the defenders give up the redoubts of the re-entering places of arms, since the besieger finds no difficulty in occupying them, by blowing down the revetments and making a lodgment.

Whilst the bastion is being breached, and its flanks are being silenced, the counter batteries at the salient of the ravelin have completed a breach in the face of the bastion. This breach is approached by zig-zags carried along the ditch of the ravelin, and that at the salient of the bastion by a descent into the ditch, or by a sap striking out of the ditch of the redoubt of the re-entering place of arms into the main ditch. Both breaches may thus be assaulted at the same time.

When the bastion of attack is retrenched, the besieger, instead of assaulting the breach, forms a lodgment on it, and advances by sap right and left to the counterscarp of the retrenchment when the mine is employed, as was done for the redoubt of ravelin. Should there be a further retrenchment, either the escalade or the mine are had recourse to, or a battery is constructed in the terreplein of the bastion.

It is admitted that under ordinary circumstances the siege would last from 23 to 25 days; six days more must be reckoned when there is a cavalier in the bastion.

CHAPTER XIX.

SYSTEMS OF CŒHORN.

(296). In 1685 Cœhorn (460) published 3 systems of Fortification for aquatic sites, the first of which he partially applied to the fortresses of Breda, Nimeguen, Namur, Berg-op-Zoom, and Manheim. His method is called the *improved Dutch method*, in opposition to the old method of Freytag (459). He borrowed much from his predecessors, Durer (441), Freytag (459), Speckles (442), &c., but his inventive genius enabled him to suit the art to the ground, and his method is so thoroughly practical, that it is, even at the present day, admitted to be the best for aquatic sites. He insisted on the following principles. All masonry, except the exterior scarp of the orillon, must be well covered; the terreplein of the covered way, and the bottom of the dry ditches must be on a level with the water, so that the besieger, unable to excavate a trench without finding water, and therefore to construct lodgment and obtain cover, is obliged to bring a great quantity of material; the outflanks should cover the flanks, and as these constitute the chief defence, long flanks should be preferred to long faces; the garrison should be able to make sorties at all times, with safe means of retreat; the outworks should be so isolated from one another, that the capture of one of them may not cause the loss of the others; the strength of a fortress chiefly consists in the number of works well flanked; the enemy should be exposed everywhere to cross fire; the advantages of wet and dry ditches should be combined; the outlay may be reduced by making the ditches of different depths, and lastly, each polygon requires a special tracing (460).

(297). In the first system Cœhorn supposes that water is to be found at 4 feet below the surface. We give here the outline for a front of the hexagon.

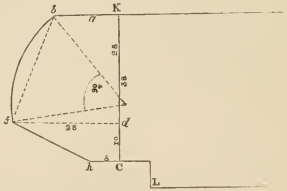
The front A B is equal to 300 yards; the curtain C D = 150 yards; the capital B E of the exterior bastion is 150 yards. The lines of defence are drawn from the flanked angle E, F of the bastions to the extremities C, D of the curtain. The length of the faces is determined by describing arcs of circles from the flanked

Fig. 567.

angles as centres and radii equal to the lines of defence, so that E C = E G, and F D = F K. The chords G C, D K of these arcs, give the original flanks which will hereafter be modified.

The faces of these bastions are not revetted, and the magistral represents the intersection of their exterior slopes with the water. At the shoulder angle a casemated building or orillon is constructed. Its long side $k\,c$, measures 38 yards, and is perpendicular to the face; its short one is traced by producing the face from

Fig. 568.



K to b 17 yards. Taking K d = 28 yards and drawing $d\,f$ parallel to $b\,k$ and = 28 yards, the line $b\,f$ is the chord of the round face of the orillon, the face itself is an arc of 60°. For the gorge erect $h\,c$ = 8 yards perpendicular to K c, and join $f\,h$.

The total thickness of the outer bastion, measured at the level of the water is 15 yards. The escarp of the inner bastion is parallel to the lines of defence and 45 yards inwards, so that both bastions are separated by a dry ditch 30 yards wide. The shoulder angle L, is found by producing the inner gorge of the orillon 8 yards to q, and drawing q L perpendicular to the face.

The main ditch is 48 yards broad, measured at the salient of the outer bastion perpendicularly to the face, and its counterscarp is directed on the shoulder angle L of the inner bastion.

Authors do not agree in the tracing of the flanks, they are generally too straight; the following method is more conformable to the plans of Cœhorn: on the part D o of the original flank describe an arc of 60°, and 30 yards inwards describe a concentric arc L P.

The outer flank is not revetted. The curtain is connected with the inner flank by a brisure D P, part of the line of defence, and it is revetted as well as the brisure and this flank.

The tenaille is unrevetted, its flanks are traced by measuring 280 yards on the line of defence from E to R, and erecting R S perpendicular to that line: the faces and the broken curtain are on the lines of defence.

The demi-gorges of the ravelin are 110 yards each, measured on the counterscarp of the main ditch; the faces are traced so as to form a salient angle of 70°. They are not revetted, and as in the outer bastion, the magistral represents the intersection of the exterior slope with the water; the thickness is 13 yards. The escarps of the inner ravelin are parallel to the magistral and 43 yards inwards, leaving before them a dry ditch 30 yards broad. A harbour of 20 yards radius is cut in the gorge.

The bastions are covered by earthen counterguards 18 yards thick, whose length is limited by the counterscarp of the ravelin. Their ditch is 28 yards broad.

The ditch of the ravelin is 36 yards wide, the covered way 24, the glacis 50. The re-entering place of arms is traced by setting 50 yards each way on the crests of the glacis and drawing the faces perpendicular to those crests. In front of the faces and at a distance of 13 yards is a loopholed gallery sunk in the glacis. Inside the place of arms is a reduit formed by a loopholed wall: its demi-gorges $= 25$ yards, and its faces are parallel to those of the re-entering place of arms. The covered way is separated from the place of arms by traverses 18 feet thick.

The details of this front differ so much from those of the bastion system, that it is necessary to dwell a little over them.

(298). *Inner bastions.* The parapet of the faces and flanks of the inner bastions has a command of 22 feet; it is 20 feet thick for the faces, and 24 feet for the flanks. The escarp of the faces is only 10 feet, and that of the flanks 9 feet above ground; so that the crest of the faces and flanks of the outer bastions,

Fig. 569.

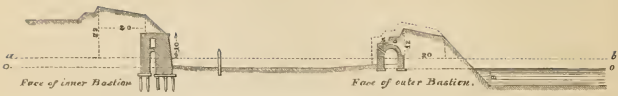
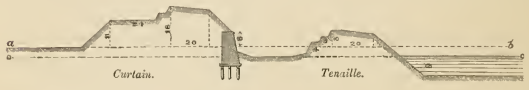


Fig. 570.

respectively with 12 and 11 feet command, well cover the masonry of the enceinte. The curtain is also protected by the tenaille, its masonry rising only

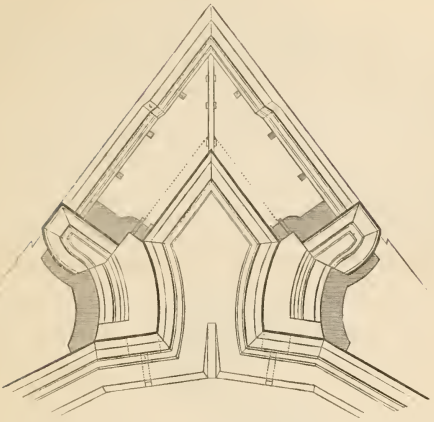
Fig. 571.



6 feet above ground, whilst the parapet of the latter is raised 8 feet. The flanks of the tenaille, however, have only a command of 3 feet, so as not to mask the fire of the outer flanks.

Outer bastion. The faces of outer bastions are secured from enfilade by a bonnet 3 feet high and 45 yards long, their terreplein is only 5 feet wide. The crest of the curtain has a command of 18 feet only, so that there is a difference of 4 feet between the level of its terreplein, and that of the flanks. It has the inconvenience of interrupting the communication, and exposing the higher rampart to the enemy's projectiles. This difference is not represented in the plan.

Fig. 572.



The outer flank has no rampart; its banquette is only 10 feet wide, so that the besieger after the capture of the orillon, will find very little earth for his lodgment. During the siege, the banquette is widened to 24 feet by wooden constructions so as to receive artillery. A coupure 7 yards wide, prevents the enemy from escalading the inner enceinte from the outer flank.

The dry ditch between the outer and inner enceintes being excavated to the water level, the enemy will not be able to sap across it.

A casemated gallery, loopholed for musketry and divided into compartments by transversal walls, both for the sake of ventilation and successive defence, is constructed under the faces of the outer bastions. Some doors enable the defenders of the dry ditch to retire within; and steps erected at intervals establish communication between this dry ditch and the banquettes of the outer faces. Along the capital, Cœhorn constructs a caponier opening into that gallery, its walls rise only 1½ feet above the bottom of the ditch; they are loopholed and covered with timber and earth, and in order that the communication across the ditch may not be interrupted steps are arranged along the gallery. The sill of this is 4½ feet

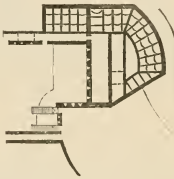
Fig. 573.

Caponier in capital.

below the water level, so that it might be flooded as soon as the defenders are obliged to abandon it. The revetment of the face of the inner bastion consists of two walls with 6 feet foundations erected on piles, they form a counter-gallery which communicates with the caponier.

The *orillon* or stone tower, is destined to cover the flanks and defend the dry ditch. The parts of this building exposed to the enemy's fire, are made very strong. The escarp wall, 6 feet thick at the level of the water and 4 feet at the cordon, is supported by counterforts 2 feet thick, placed 9 feet apart. These counterforts are connected by arches and support the parapet above, and in order to render breaching still more difficult, and to prevent the earth from falling after the destruction of the escarp, the piers are connected by two walls 1½ feet thick,

Fig. 574.



convex towards the rear. A straight wall unites the inner extremities of all the counterforts. The empty space between these vaults is filled with dry earth and stones, to render a lodgment difficult and dangerous. Below the masonry represented in the plan, there is another row of counterforts 14 feet long, also connected by arches and closed by a convex wall. The foundations of the escarp are 3 feet below the bottom of the main ditch, therefore 9 feet below the water level.

Part of the face of the outer bastion, 17 yards in length, is similarly revetted, so that the enemy cannot come close to the orillon to spring a mine; the projection of the orillon would otherwise prevent this part of the face from being flanked.

Behind the revetment, the orillon contains three vaults; two of them, the interior ones, serve as magazines, the third, which communicates with the gallery, contains a battery of six guns flanking the dry ditch. The front wall of this casemated battery is rectangular in profile and 4 feet thick. It rises only 14 feet

Fig. 575

above the ground, in order that the bonnet of the outer face, 15 feet high, may cover it; and to prevent the enemy from escalading it from the parapet of that face, 12 feet high, the revetment is surmounted by a small wall 1 foot thick, 4 feet high, which, however, may be destroyed from a distance.

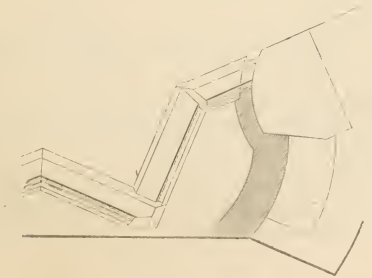
A staircase leads from one of the interior magazines to the platform of the orillon, which is 16 feet above ground, and has a parapet of 24 feet along the parts most exposed to the enemy's fire, and of 16 feet along the part flanking the dry ditch.

A wet ditch, 12 yards wide, and 6 feet deep, separates the tower from the dry ditch.

Of the wall that extends from the orillon to the shoulder-angle of the inner bastion, and which is 8 feet high, 1½ feet thick, the part adjoining the orillon is pierced with three embrasures for guns to flank the dry ditch, whilst the other part is pierced with two doorways leading each to a drawbridge across the wet ditch, one in front, the other in rear of a row of palisades planted 5 yards before the foot of the escarp of the inner bastion. This palisading, with its numerous barriers, is intended to secure the retreat of the defenders when making sorties against the besieger in the dry ditch. Two guns firing through embrasures cut through the wall between the doorways, flank the part of the ditch that extends from the palisading to the escarp.

Under the brisure of curtains there is a casemated battery for 4 guns that sweep

Fig. 576.



Y

the ditch between the flanks: it is 16 yards long and 6 yards wide. Before the outer flank and the circular face of the orillon there is a wet ditch, 12 yards wide and 7 feet deep, which serves as a harbour for boats.

The communication between the various parts of the enceinte and the place is established by means of posterns, under the brisure of curtain, which lead to the casemated battery and thence by a door to the dry ditch between the flanks. The platform of the orillon is ascended from the ditch by a ladder, its interior by a door opening into the vaulted battery. This battery also communicates with the loopholed gallery, the gallery with the caponier in capital, and the caponier with the gallery behind the escarp of the inner bastion. A postern under the curtain leads to the tenaille. The communication with all the outworks is by boats; they pass under an arched cutting adjoining the orillon.

(299). The *counterguard* is destined to prevent the counter-batteries from injuring the three flanks: the enemy must take it and breach it before he can fire through it.

FIG. 577.

It is defended exclusively by musketry, and its terreplein 5 feet wide, offers no room for a lodgment. Its command is 12 feet.

Ravelin. The dispositions in detail are similar to those of the bastions. The crest of the inner ravelin is 18 feet, and its escarp 10 feet above ground, so that its masonry is well covered by the outer faces whose parapet has a command of 12 feet. These faces are too narrow to offer available space to the enemy. A

FIG. 578

bonnet 3 feet high and 43 yards long at the salient, protects the rest of the faces from enfilade. For 40 yards from the main ditch the crest is raised 2 feet, to give sufficient height to the gallery of communication which, we shall see, is constructed under that extremity.

The terreplein is supported by a counterscarp wall and is reached by means of stairs. In the inner ravelin the terreplein is made wide enough for artillery at the salient and for 40 yards along each face.

Fig. 579.

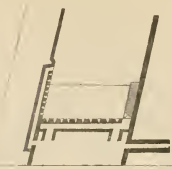
The dry ditch is flanked by a caponier erected 12 yards from the main ditch; it consists of two walls 8 feet apart, 1½ feet thick, and 7½ feet high, covered over with planks and 1½ feet of earth. The wall flanking the ditch is loopholed for musketry. A banquette with two steps in rear enables the defenders to fire over

Fig. 580.

Caponier of ravelin.

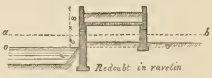
it as over a common parapet. Two small doors, one at each end, give access to the caponier from the ditch behind it. In front is a wet ditch 12 yards wide and 5 feet deep, which is flanked by a loopholed gallery under the terreplein of the lower ravelin. A postern leads from the inner ravelin to the ditch in rear of the caponier, and from this ditch to that in front the communication is maintained in three different ways,—through the caponier, over a drawbridge placed close to the escarp of the inner ravelin, or by mounting on the caponier itself, hence ascending the terreplein of the lower ravèlin, the stairs of which lead to the dry ditch, or by means of the loopholed gallery under the extremity of the face of the lower ravelin, two doors of which open in rear of the caponier, and two doors in front of the wet ditch.

Fig. 581.



The drawbridge is protected by a palisading planted 6 yards from the escarp and destined, as in the bastion, to secure the retreat of the sorties made in the dry ditch. A caponier in capital, similar to that of the enceinte, and reached by a postern under the salient of ravelin, leads to a counterscarp gallery constructed under the salient of the outer ravelin. This gallery, loopholed for musketry, serves as a guardhouse to fire into the dry ditch. The interior of the ravelin is excavated to within 6 inches of the water, and to protect the retreat of the garrison, a pentagonal redoubt of masonry, of about 8 yards faces, is erected at the landing place. It consists of walls 1½ feet thick, loopholed and covered with beams, and 3 feet of earth: on this roof, to which a staircase gives access, infantry is placed to defend

Fig. 582.



the interior of the ravelin with a second tier of musketry fire. The men are protected by a parapet wall 1 foot thick and 4½ feet high. As the total height of masonry above water is only 14 feet it is covered by the ravelin. A double row of palisades, planted as in the diagram, facilitates the retreat and prevents the besieger from entering the redoubt with the defenders. The men retire behind the first row, then behind the second, and enter the redoubt by a door in the flank.

(300). The *covered way* is 24 yards wide, but the enemy cannot construct any cover on it because it is on a level with the water at its gorge, and it rises only 1 foot at the foot of the banquette.

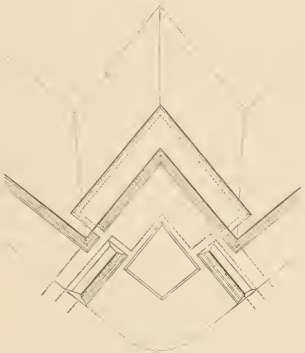
The crest of the glacis is 7½ feet above the terreplein, and the walls of its reduits have the same height. The reduit has no roof, and is entered by a door placed at the re-entering angle: it flanks the place of arms, and its walls 1½ feet

Fig. 583.

thick are covered from the batteries at the salient by traverses 18 feet thick and 7 feet high.

The gallery is 8 feet wide and 6½ feet high inside; its floor is 4 feet below the surface of the glacis, so that the loopholes give a sweeping fire along its surface. It is covered with timber and earth, and is entered by two similar galleries 6 yards from the extremities of the faces of the re-entering place of arms.

Fig. 584.



The covered way has a double banquette throughout, with a row of fixed palisades planted on the upper banquette: the row along the faces of the re-entering place of arms is continued to the ditch, and pierced with barriers for communication. A second row protects the traverses and the reduit: it is of a peculiar construction, the palisades, which are at 3 feet in front, being inclined, and raised or lowered at pleasure. Strong posts are planted at intervals, and have collars to receive the pivots of the horizontal axes to which the palisades are attached. Iron bolts admit of their being fixed at any inclination.

(301). Such is the first system of Cœhorn, the properties of which we shall now pass in review. The reputation of Cœhorn, as an engineer, is not so much due to the systems he proposed as to the application he made of the principles they involved. Instead of clinging to an invariable tracing, he proclaimed the

necessity of altering the outline to suit the ground. At Groninguen, for instance, he employed a tenaille tracing; and the fortifications of Berg-op-Zoom, in which part only of his first system is applied, are certainly among the best of Europe.

The principal value of this first system consists in the simultaneous employment of dry and wet ditches. The dry ditches enable the garrison to make sorties, and to dispute the ground more energetically than if the ditches were exclusively wet. The besieger cannot easily lodge himself on the outer faces of the ravelins and bastions, nor can he sap acro s their ditches; hence, when he has breached the inner work through openings cut into the outer one, the garrison has a fair chance of resisting the assault.

It will, however, be seen at a glance, that this tracing gives acute angles for the bastions of all polygons: the faces will, therefore, be exposed to enfilade, and the defect is so much the more serious, since the upper and lower faces, the counter-guards and the covered way, are parallel, and the enemy has no difficulty in finding a proper position for his ricochet batteries. The saliency of the ravelin is not sufficiently great, because the counterguards diminish the re-entering space; therefore, the besieger will attack two bastions and one ravelin, and crown simultaneously the three salients, which are nearly in a straight line.

Passing to the details, we find that there is not much room for artillery to act on the approaches, the batteries at the salient of ravelin being insufficient for the purpose. The three flanks defend the main ditch very well, and can mount three times as many guns as the besieger can bring to bear against them; the two lower flanks, if exposed to splinters from the scarp in rear, are, at all events, well protected against enfilade and reverse fire by the orillon, but the wall of the casemated battery of this orillon is very weak, and when it is destroyed by the ricochet batteries, to the fire of which it is rather exposed, the dry ditch is deprived of defence, and the mass of the orillon prevents the flanks of the collateral bastions from remedying this, since they cannot command a view of that ditch.

The faces of the inner bastion are the only available space on which to mount guns to fire on the batteries of the first parallel, and as these faces are short, these guns are not capable of producing a good result: those of the ravelin are also too few. The narrowness of the terreplein, intended to prevent the besieger from establishing his lodgment, is carried to excess, especially in the ravelin, which ought to fire on the approaches along the capitals of bastions.

The covered way despite its great width, affords no material to the enemy to obtain cover: its places of arms are well disposed to facilitate sorties, but the reduits and the galleries are defective. The former may be destroyed from a distance by vertical fire, because its walls are too thin, the latter are exposed to direct fire, and afford cover to the besieger, when he has advanced so far.

The counterguards, defended only by musketry, cannot present a serious

obstacle to the passage of the ditch: they leave between their extremities and the ravelin a dangerous opening. They were intended to cover the flanks, but they are so narrow that an opening may be cut through, and the three flanks become thereby exposed to the counter-batteries established at the salient of the covered way.

The walls of caponiers, galleries, &c., are too weak, and are liable to be destroyed before the time when they are wanted for the defence. The communications with the outworks are difficult: the access to the orillon would be very precarious should the wall that connects it with the inner bastion be destroyed. The caponiers in capital are liable to be flooded, since they are below the water level.

The corrections which have been recommended are: to place the orillon at the shoulder angle of the inner bastion; to increase the saliency of the ravelin, giving 60° to its angle; to close the opening of the counterguards, by producing them as far as the gorge of the ravelin; to construct a strong reduit in the re-entering place of arms; to give bomb-proof vaults to the galleries, caponiers, &c., and to raise their floor above the water level.

(302). *Second System.*—The second and third systems of Cœhorn have not been applied, and it would be difficult to do so since the fortifications require five times as much ground as the town itself, and this would scarcely be large enough to lodge the garrison and its magazines.

In the second method, which he proposes for an heptagon, for a site where water

FIG. 585.

is to be found at 3 feet, the inner bastion has two flanks covered by a small orillon. The tenaille with flanks parallel to these is preceded by a small wet ditch. A dry ditch with low faces and galleries surrounds the whole front. The ravelin is connected with these faces, and has a gallery likewise: its reduit is a casemated redoubt, covered with a platform of earth. Outside the wet ditch is a continuous enceinte, divided into several parts by means of traverses: it has reduits of masonry at the salient and re-entering angles. The reduits of the re-entering angles are connected with the redans and their curved flanks before them, which are provided with a gallery.

A wet ditch and a covered way, similar to those of the first system, precede the whole. The profiles are the same as in the first system, except that of the inner bastion, whose command is greater by 6 feet.

Most of the defects of the first system are remedied: the communication with the ravelin is secure; the opening of ravelin is closed; and the orillon does not prevent the triple flank from defending the dry ditch.

(303). In the third method, proposed for an octagon, and a site where water is found at 5 feet, the enceinte is formed of bastions with simple flanks and simple faces, and is surrounded by a wet ditch. The place of the ravelin is occupied by a detached bastion constructed exactly like a bastion of the first system. Ordinary ravelins are placed on the capitals of the bastions of the enceinte, and

Fig. 586.

counterguards on the salient of the detached bastions. The covered way remains the same. The profiles are also the same as in the first system, except that of the bastion of the enceinte, whose command is greater by 4 feet.

Here the defects re-appear: the orillon prevents the enceinte from defending the dry ditch of the detached bastion, but, what is far worse than before, the enemy can, from the glacis of the re-entering place of arms, breach the enceinte.

(304). *Attack.*—We have already seen that the attack on Cœhorn's first system, must be made on two bastions and one ravelin, and in order that every part of the front may be taken at reverse and enfilade, the besieger will have to crown five salients besides the four re-entering places of arms.

The first parallel is traced as usual at 600 yards, and embraces the collateral ravelins so as to ricochet the faces that command the attack. The number of ricochet batteries is necessarily great, not less that 44, implying a minimum train of 78 pieces distributed as follows: a battery of 3 guns against each of the four faces of the two inner bastions; one of 2 guns against the six faces of the inner ravelins; one of 1 gun against each of the four faces of the lower bastions, the six faces of the lower ravelins, and the four faces of counterguards; a battery of 2 howitzers against the ten branches of the covered way; a battery of 2 howitzers or mortars, against each of the dry ditches of ravelins and bastions.

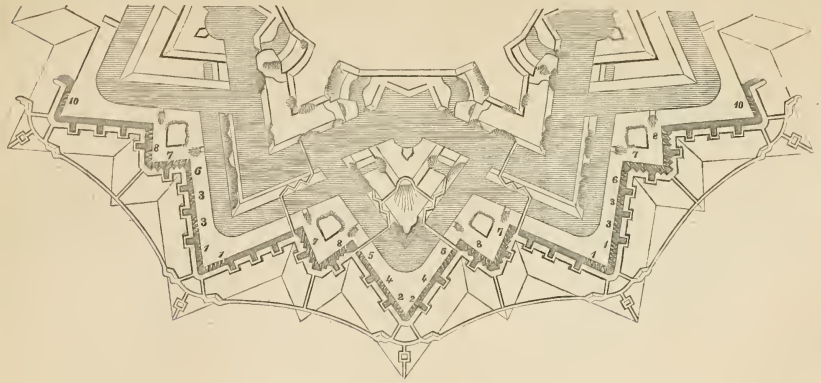
As the approaches are not exposed to more artillery or musketry fire than in Vauban's system, the progress of the attack will be the same as far as the crowning of the glacis, with this difference, that there will be five trench cavaliers which will be connected by a fourth parallel, and that, owing to the impossibility of the defenders mounting guns on the counterguards, the crowning will be less difficult. The defenders, it is true, may place some artillery in the dry ditches, especially near the salients, to fire on the crowning over the low faces, but they cannot prevent the besieger from arriving on the 13th night at the salients of the covered way. On that night, he will debouch from the inner extremities of the trench cavaliers, and begin the crowning. Next day he continues the operation, and constructs the batteries 1, 1 and 2 2 at the three salients. They are intended to destroy the traverses, and the walls of the reduits of re-entering places of arms, and to fire afterwards on the faces of ravelins and bastions; they will be ready on the 15th.

The crowning continues in the meanwhile, and on the 16th the re-entering places of arms being crowned and connected by double saps with the 4th parallel, the operation is completed.

From the 15th to the 18th, the besieger completes and opens his several batteries, which must chiefly consist of mortars and howitzers. Besides the batteries 1, 1, 2, 2 already in operation, the former attempting to destroy the

faces of lower ravelin near the gorge, to breach the upper face through the opening, and the latter to do the same with the bastions, he will have 3, 3 to ruin the faces of counterguards, then enfilade the banquette of the face overlooking the attack, and afterwards fire at the flanks of the enceinte; the faces of counterguards overlooking the attack, are not breached

Fig. 587.



because they afford cover against the fire of the bastions, whilst the openings left between the ravelin and their extremities, are sufficiently wide for batteries 2, 2 to fire through. 4, 4 to enlarge the breeches made by 2, 2; 5, 5 to destroy the face of lower ravelin near its salient, then to enfilade the opposite banquette, destroy the caponier and breach

the salient of upper ravelin; 6, 6 to fire on the flanks of the front of attack when an opening has been made through the counterguards, and destroy the casemate of the orillon; 7, 7 to cut through the faces of the lower bastions, destroy the draw-bridges and walls of the dry ditches, enfilade the flanks of the tenaille, destroy the casemates under the brisure, and finally to breach that brisure; 8, 8 to ricochet the faces of upper bastions after the destruction of the lower faces, take the upper flanks at reverse; and destroy the casemated battery of the orillon; 10, 10 to take the upper flanks at reverse, and destroy the traverses which the garrison will throw up to cover them.

On the 17th, four descents into the covered way have been effected; the besiegers debouch from the extremities of the re-entering places of arms behind the traverses, and are either blinded or covered by epaulments of gabions, fascines and earth. The passages of the ditch of the ravelin and of the counterguards also begin.

On the 18th, the passages are completed, the besieger occupies the faces of the lower ravelin, erects an epaulment across its dry ditch to the salient of inner ravelin, and by zig-zags cut in the parapet of the lower faces, arrives opposite the breaches made at the extremities of the upper faces; the counterguards are occupied at the same time, and similar zig-zags lead to the points where the passages of the main ditch are to be made.

On the 19th, the inner ravelin is taken, and the batteries continue their fire to facilitate the construction of the passages.

On the 21st, the passages reach the faces of the lower bastions, and as the enceinte is breached on the faces and flanks of bastions and at the brisure of the curtain, the assault may be given on the 22nd.

In this attack, it has been admitted that the earthern parapets may be destroyed by shells filled with powder. Bousmard and even Cormontaingne were of opinion that, in two or three days a breach could thus be made through a face 18 yards thick. The projectiles in destroying at the same time the galleries, caponiers, and the casemate of orillon, ruin the defence of the dry ditch, and the dispute on which Cœhorn strongly relied to protract the siege. He contested the possibility of cutting with artillery an opening through the lower faces On that hypothesis it is clear that the attack would proceed much more slowly, since it would become necessary to occupy these faces, and establish breaching batteries on them, or cut an opening with the mine. The counter-mines prepared in the ravelin and bastions, would then delay the besieger on these faces, and the siege might last 36 or 40 days, but the improvements in artillery leave no doubt now as to the possibility of cutting an opening through those thin faces with live shells.

CHAPTER XX.

PERMANENT FRONT.

SECTION I.—Tracing of Fortresses.

(305). Great importance has hitherto been attached to the construction of regular fortresses. Vauban himself, whenever he could do so, adopted a regular polygon for the base of his tracing, and such places were called "*royales.*" The perfect equality between every front, far from being advantageous, is a serious inconvenience. Every bastion is in fact equally liable to attack, and if any addition, such as retrenchment, countergnard, &c., be made to one front, the same outlay must be made for all of them, otherwise the enemy will attack those fronts the strength of which has not been increased. The only advantage of a regular tracing is to enclose a greater interior space by a given number of sides.

Fig. 588.

If we now consider a place in which several fronts are traced on the same straight line, we readily perceive that the angles of the polygon are only exposed to attack, since, the prolongation of the faces of the intermediary bastions falling on the ravelins, the enemy cannot enfilade them. These bastions become still less exposed when they are placed in a more and more re-entering position by the addition of works before the exposed angles; and even supposing the enemy attacked them, he would not find room at the salient of the covered way to establish his batteries.

This property of fronts in straight lines seems to have been overlooked by ancient engineers, and although one of them, Fabre, proposed in 1629 to construct fortresses on squares, the sides of which should be divided into several

fronts, thereby offering only four bastions of attack, yet it is only Cormontaingne who succeeded in drawing attention to this subject. He recommends the construc-

Fig. 589.

tion of fortresses on a triangle, somewhat of this form, the small angle of which is truncated and replaced by a citadel.

In this manner the enemy will have only two bastions to choose between for attack, and the outworks, with the exception of the covered way and the glacis, may be dispensed with on the fronts occupying the straight lines.

This method, however, implies a place of great extent, and cannot be invariably adopted, especially as the shape of the town greatly influences that of the fortifications, but it is a standard at which we should aim. It is impossible with fewer than nine fronts, excellent with from twelve to twenty-four, and perfect when one, two, or even the three salients can be protected by serious obstacles, such as inundations.

The presence of rivers has also a great influence over the general outline. If the town is traversed by a large river, it is advantageous to rest two salients on it. The enemy will then find a difficulty in developing his attacks on them,

Fig. 590.

inasmuch as he must occupy both sides; the other fronts being traced on oblique lines, there would be but two bastions of attack situated on a line perpendicular to the river. This disposition is certainly preferable to that in which the river intersects a straight line of the perimeter, since the latter can only protect a space

equal to its own width, and requires particular dispositions of detail, as high quays of masonry acting as flanks, and parapet bridges acting as curtains, together with strong iron gates to close the arches, &c.

Small rivers are more precious to the defence, as capable of producing inundations on which to rest several fronts.

The triangular form is particularly applicable to those towns situated at the confluence of two rivers.

Fig. 591.

Lastly, when the place is all on one side of the water, the greatest possible number of fronts is traced along it, and the rest of the perimeter is bent into a convex outline.

SECTION II.—Tracing of a Front.

(306). When a place is to be constructed, the first thing to determine is the polygon to be fortified. It is an *exterior polygon* when it surrounds the fortifications of the enceinte, and an *interior polygon* when it surrounds the town within the fortifications. The place is said to be fortified *inwards* or *outwards*, accordingly as the outline of each front is traced on the side of the exterior or interior polygon.

Some ancient engineers recommend fortifying outwards, because the interior side really limits the fortified space, and is rendered compulsory by the form of the town; but Vauban, and with him modern engineers agree, prefers the exterior side, because bastions being the chief parts of the defence, their salients must be advantageously placed on the ground, and besides, as they must be flanked within easy range, it is necessary that their position be settled before fixing that of the flanks. Both principles are correct; and it is only by due attention paid to the exterior as well as to the interior side, and therefore only after a few preliminary essays, that the engineer will hit upon a good outline.

(307). Since the various fronts of fortification have not the same length, it follows that the formula laid down for their tracing cannot be always applied. With a front of 360 yards the formula giving corresponding curtains, flanks, &c. sufficiently supplies the necessities of defence; but when the front is less, the

curtain becomes too small, and as this reduction is not based upon principles of defence, the usual relief cannot permit the flanks to defend the ditch in front of that curtain. Besides, it may be impossible to trace a front perfectly symmetrical. It is therefore necessary to record the principles on which each part of a front should be constructed.

(308). The *relief* is the first consideration. It is now admitted that to prevent escalade a scarp wall should be at least 30 feet high, of which 8 feet may be above the ground, since the glacis covering the masonry has usually that command. The crest of the parapet can barely have a command less than 16 feet, 3 feet for the dip of the superior slope, 5 feet for the exterior slope, and 8 feet for the part of the escarp above the level of the ground.

Should any outwork exist between the enceinte and the glacis, a far greater command must be given to the enceinte, 20 feet, 24 feet, or more. A small command has the serious inconvenience of giving small remblais, which it becomes difficult to equilibriate with the deblais.

(309). The greater the relief, the stronger the profile, but the greater also the dead angles; and although the ditch may be raised before the curtain, and deepened before the bastions, it is not always practicable. The flanks, as we have said (94, 275), must afford a view of the ditch before the middle of the curtain, and as their superior slopes are at $\frac{1}{6}$, the distance between their crests is twice 38×6, or 456 feet. As, however, it is quite sufficient to see 2 feet above the bottom, the distance may be taken at 420 feet, which deduction made on the two parapets, with their slopes 24 feet each, leaves 372 feet, or 120 yards, in round numbers, for the minimum of the *curtain*. The maximum should not exceed the range of the new musket: but the cases in which such a curtain would be required are exceedingly rare, and it is usual to keep nearer to the minimum.

(310). As for the *flanks*, they must defend the salient of the bastions: the old engineers had fixed the maximum of the lines of defence at 250 yards, and as the old musket could scarcely carry that distance, special weapons, called wall-pieces, were necessary. They may now be dispensed with, and the lines of defence increased to 300 yards. Some engineers say 500 yards or more; but can a soldier see a man in the trenches at that distance?

The direction of the flanks perpendicular to the lines of defence is not so good as that given by Vauban, because the angle of the flank is too open to permit the defence of the foot of the curtain; therefore the French engineers now trace the flanks, forming an angle of 99° 30′, with the curtain; a construction very nearly coinciding with that of Vauban.

The space at disposal and reasons of economy may limit their length. When destined to flank bastions not exposed to attack, they may answer their purpose with two guns, and their length may be reduced to 15 yards, more especially when

they cannot command a view of the ground the enemy can occupy. Such cases seldom occur, and as the flanks are the most essential part of a front, there is advantage in making them long; but 50 or 40 yards, dimensions adopted by Vauban and Cormontaingne, are quite sufficient, since they outbalance the space the enemy can dispose of at the salient of the covered way.

(311). The *faces* of the bastions should be traced on the lines joining the extremities of the flanks to those of the curtain; in this direction the flanks are said to be "rasant," whilst they are "fichant," when they are met by the faces produced. It is clear that "fichant flanks" are faulty, the part left between the face produced and the curtain being useless. When the faces are fichant on the curtain, they are better defended, because the flanks can readily discover the breach, which can even be seen at reverse, and the curtain itself may, with oblique embrasures, contribute to their defence; but they become less inclined upon the front, and may the more easily be enfiladed by the enemy.

The length of the faces necessarily depends upon that of the curtain and of the line of defence, a small curtain permitting the construction of large bastions well fitted to receive interior retrenchments. When the front is not exposed to attack, there is some advantage in having a long curtain and short faces, the former being always less liable to enfilade.

(312). The consideration of the flanked, and of the diminished angle, may further induce the engineer to modify the tracing. As a rule, no *flanked angle* should be less than 60°. As for the *diminished*, Vauban and Cormontaingne's constructions usually make it equal to 18½°. This limit should be maintained, because the field of a gun firing through an embrasure being very nearly the same, 20° at the utmost, the first gun of the flank can see the escarp both of the curtain and the opposite bastion; and a greater opening, besides being unnecessary to the defence, gives a greater depth to the fortification and increases the amount of masonry.

(313). All the preceding considerations must be weighed before definitively adopting a tracing, and several essays will be found necessary before harmony can be established between each part. The ground may vary, symmetry may not be possible, the relief, or the length of curtain or other part, may be fixed, *a priori*, and the *tracing on condition*, as it is termed, becomes a problem which a knowledge of Euclid and of the foregoing principles will render easy.

To illustrate how the dimensions of fronts may be obtained from conditions, let us construct a front such that the escarp of the curtain may be seen from the

FIG. 592.

flanks within 3 feet of its foot, taking the relief of one flank equal to 40 feet, of the other to 34 feet, the wall of the escarp being 30 feet high, and the lines of defence 280 yards long.

Take A B for the bottom of the ditch in front of curtain, and draw a line parallel to it, and 3 feet above. On this line take any point C, and through it draw two lines inclined at $\frac{1}{6}$ to D and E, respectively 40 and 34 feet above A B. Finish the construction of the parapets, and F G will be the length of the curtain.

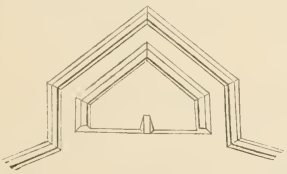
FIG. 593.

Now, take $f\,g$ as the length in yards, and draw $g\,\mathrm{M}$, $f\,\mathrm{N}$ inclined on $f\,g$ at $\frac{1}{7}$ for an hexagon or higher polygon ($\frac{1}{4}$ for a square, $\frac{2}{7}$ for a pentagon), and taking $g\,\mathrm{M} = f\,\mathrm{N} = 280$ yards, the front required will be M N.

SECTION III.—INTERIOR WORKS.

(314). *Cavaliers* are works of great command constructed on the terrepleins of bastions or curtains.

FIG. 594



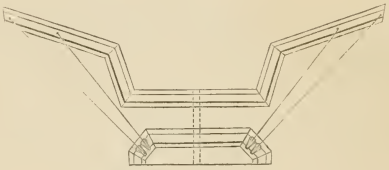
These works should not be commanded by the parapet of the enceinte; therefore they are only erected in full bastions, the parapet of which they command by from 2 to 4 yards. They are intended to overlook hollows which an ordinary command cannot bring to the view of the defenders; to cover the flanks from reverse and the curtain from enfilade fire; to prevent the besieger from making a lodgment in the breaches, and to further extend the action of the fortress, even from the very beginning of the siege. But they have the very serious incon-

venience of confining the space on which the garrison has to defend the breaches to such a narrow strip that an active defence is no longer possible: their great command is not favourable for the defence of the breaches which are so near; and they occasion great outlay. We have seen one of them organized as an interior retrenchment in the modern system, and to the defects enumerated above we may add that it has dead angles in its ditch, and that the communications with the bastion are precarious.

Cavaliers are therefore recommended merely to command hollows, which the besieger might turn to advantage; if possible, they should be erected in the bastions collateral to the one attacked, and leave at least 12 yards terreplein clear before them. Their faces and flanks should not be parallel to those of the bastion, to avoid enfilade by the same batteries. When their scarps are revetted they should be constructed still more in the rear, because splinters may seriously inconvenience the defenders of the bastion.

(315). Cavaliers have occasionally been erected on the curtains with a command of from 2 to 4 yards over the parapet of the enceinte. They form an excellent position for heavy guns, with which much damage can be done to the works of the

Fig 595.



besieger, whilst they remain almost safe against enfilade. They are also extremely useful for the establishment of casemates, and by the addition of small flanks they may contribute to the defence of the breaches more efficiently than bastion cavaliers. It is usual to revet them, and to trace their escarp 15 yards in rear of the crest of the curtain; a thickness of 22 yards is sufficient. They are not frequently constructed because they hinder the communications, yet they may be seen in some places covering gates or posterns.

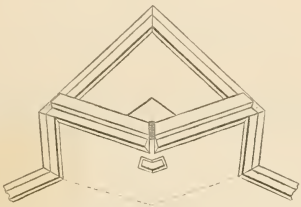
(316). *Interior retrenchments* are destined to give a garrison the means of vigorously defending the breaches without exposing the place to be carried by storm. When the fortress presents points of attack strongly characterised, these works may be permanently organized; but as in general the defenders cannot know previously which front will be attacked, it is usual to defer their construction

till after the siege has begun. Many tracings have been employed, but the chief are the tenaille, the bastion, and the straight line.

They may rest on the faces, or the flanks, or occupy the gorge of the bastion. Those resting on the faces may be turned by the breaches which the besieger may make at the shoulder-angle; those resting on the flanks may also be turned by the breach made in the curtain through the opening of the tenaille; and as for those constructed on the gorge, they cannot be turned easily, yet as the flanks can no longer defend the collateral bastions the besieger may easily take them by escalade or mining, and the retrenchment becomes useless.

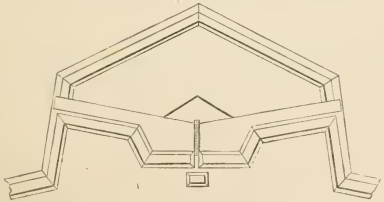
The tenaille tracing is preferred for narrow bastions: the ditch has no direct

Fig. 596.



defence, but as there is plenty of room in front for the active defence of the breach, it advantageously replaces the cavalier retrenchment. When the bastion is wide, the bastion tracing is better, as giving a greater development of fire on the breach, and as flanking its own ditch. It is to be found in some of the forts

Fig. 597.

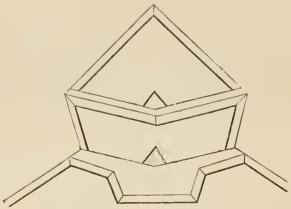


constructed at Lyons. When such retrenchment is constructed at the gorge, or rests on the curtains on the rear of the tenailles, it becomes an excellent work,

capable of a good resistance, and has the only inconvenience of being exposed by the fall of the collateral bastions left without defence.

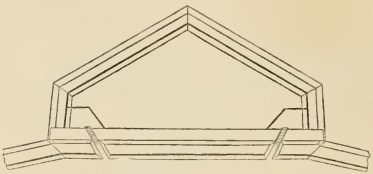
Sometimes the retrenchments are made in the same bastion.

Fig. 598.



A more simple outline is that of a straight parapet along the gorge. It leaves room in front for the defence of the breaches, and does not encroach on the in-

Fig. 599.



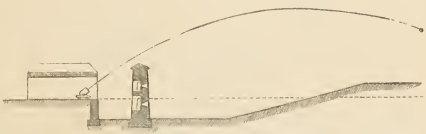
terior of the place; it is farther from the breaches, and therefore defends them better, and the two lateral bastions may be made to contribute to its defence, by merely lowering the parapet of their flanks when the besieger prepares for the assault. On the other hand, it diminishes by half the length of the flanks; but this is not very serious, since the flanks of the bastion of attack have only to protect the collateral bastions against escalade, and the inconvenience may be obviated by interrupting the ditch and parapet close to the flanks and completing them at a later period of the siege. On account of its simplicity and of the little outlay it necessitates, this retrenchment at the gorge is advocated by many engineers.

Whatever form be adopted, the parapet should have a command over the bastion: the ditch should be at least 10 yards wide, the escarp 6 or 7 yards

high, and the counterscarp not less than 5 yards. Instead of constructing posterns and ramps, it is better to cut a passage through the parapet and to cover it by redans of stockades and traverses.

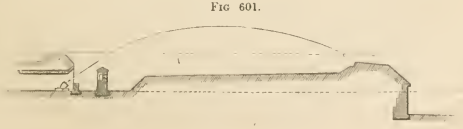
(317). *Casemated retrenchments* have been proposed by Carnot (412), to replace the various dispositions which we have just enumerated. They consist of a wall 36 feet high and 9 feet thick, erected at the gorge of the bastions, and provided with two rows of loopholes, the upper for musketry, the lower for small mortars of a peculiar description. Behind this wall is a ditch 20 feet wide, and on the rear of it stands a casemated battery formed of a series of open arches, having their axes parallel to the capital and containing two mortars each. Their platforms are on a level with the place in order to facilitate the communication,

Fig. 600.



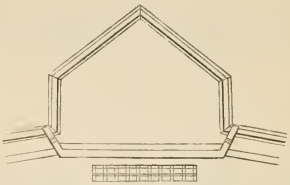
and 12 feet above the bottom of the ditch, in order to protect the gunners from the splinters of the shells that may fall between the battery and the wall. In front of the wall, a ditch 12 feet deep, rises by a gentle slope to the level of the terreplein of the bastion, to permit the garrison to make "offensive returns." In rear of these batteries, Carnot proposes a parapet without revetment and also without flank defence, but it is evidently useless, since the besieger, once master of the wall, finds no obstacle in spreading along that parapet and scaling it. Most modern engineers therefore abandon this parapet, and those who place reliance on the vertical fire of the small mortars, who believe it possible that the arches can resist the concussion of a continual fire and the fall of shells as well, and who trust that the men at the loopholes will not be seriously inconvenienced by the proximity of the battery, (and they are exceedingly few in France who do so,) recommend this sort of retrenchment. General Dufour, among others, recommends the following improvement.

Fig 601.



The wall, only 21 feet high and 6 feet thick, has only the upper row of loop holes destined for musketry, and is connected to the curtain by two flanks. The coupures before them being directed towards the extremities of the flanks of the redoubts of ravelins leave no opening to the enemy to fire through and breach the wall, and they may be *deblayed* during the latter part of the siege only. A ditch 30 feet wide runs before the wall, and separates it from the terreplein of the bastions.

Fig. 602.



The casemated battery is 6 yards in rear, with arches 17 yards long supporting an earthen parapet. One mortar only is allotted to each arched casemate, the height of which remains 15 feet as with Carnot, but the width measures 18 feet instead of 24. The upper part is widened on the outside, to resist the concussion caused by firing. There is no doubt that this retrenchment would be excellent if the wall could remain uninjured till the assault is given to the bastion. In several fortresses in Germany these interior retrenchments have been organised permanently on a different principle. A casemated building is constructed at the gorge, the lower story on the same level as the natural ground, defends a ditch in front by musketry, the second floor on a level with the terreplein of the full bastion contains artillery. The building is connected with the curtains by a revetted parapet, and a platform for artillery acting as a cavalier is constructed over it. The besieger, it is presumed, will be obliged to employ the mine exclusively, and the defence has provided for this eventuality by the establishment of a system of galleries.

SECTION IV.—Escarps.

(318). In order to increase the strength of the enceinte, and provide the ditch with a grazing fire, engineers of the 16th century employed the *faussebraie*, or a second enceinte of small command before the curtain, the flanks, and sometimes the bastions, but it was soon abandoned, because the splinters from the escarp behind it, render it dangerous for the defenders; it may indeed be called a

Fig. 603

"shot trap" for the projectiles of the enemy, it is easily enfiladed and even plunged, and as it divides the whole relief into two stories, it facilitates the escalade. The artillery does not sufficiently command the glacis, and if its relief be increased, that of the inner enceinte must also be augmented, and it becomes too great. Vauban set it aside and replaced it by the tenaille.

(319). Another disposition of the enceinte generally found in ancient fortresses, and likewise abandoned by Vauban, is the *chemin des rondes*. It is a sort of passage or berm at the top of escarp before the foot of the exterior slope, protected by a small wall forming a parapet, and used by the officers as a path to go their rounds without crossing the ditch. This chemin des rondes enables the defenders

Fig. 604.

to see the foot of the escarps at close range, to repel the enemy who has succeeded in placing his scaling ladders, and to give a double amount of musketry fire on the ditch and the outworks. On the other hand, if it has a sufficient command to give a sight of the glacis, its parapet is exposed to artillery and is soon destroyed, whilst if it is kept low, so as to fire only into the ditch and the covered way, it is exposed to enfilade all along the faces of the bastions. Its narrowness prevents the garrison from mustering in force to repulse the escalade, and when the breach is made and the assault given, the enemy spreading all along it, turns the interior defences. Modern engineers have abandoned it, but its good properties may be restored by merely tracing it before the curtain and the flanks in the following manner. The enceinte being traced, and the crests of the parapet fixed, the magistral of the curtain and of the flanks is brought ten yards forwards, and that of the faces of the bastions is produced, till it meets this new flank. Between the new magistral and the exterior slope, a chemin des rondes with a banquette is organized, the terreplein of which is kept 6 feet below the cordon, and communicates with the rampart by a passage at the extremity of each flank. Such construction reduces the outlay of masonry, since the magistral is shorter, and the thickness of the escarps may be reduced on account of the parapets being more distant. The

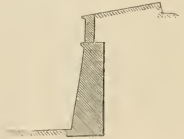
enfilade is no longer apprehended, inasmuch as the escarp of each face at the shoulder angle is capable of being easily transformed into a traverse. The crest of the parapet, it is true, should have a sufficient command over the magistral not to inconvenience the defenders in front, and this may necessitate too great a relief, but it may be obviated by lowering the ditch and the magistral of the curtain and flanks, and maintaining the former command of the crests.

(320). *Escarp revetments.*—Some places are found, the enceinte of which differs from that of an ordinary field fort only by its greater relief. It is economy alone which thus induces a garrison to dispense with a revetted scarp, for the palisades and fraises destined to prevent the escalade, are soon destroyed by the first ricochet batteries of the enemy, and the place is then exposed to attacks of "vive force." Such a disposition should only be resorted to when the ditches can be filled with water, as will be explained hereafter.

The revetment of the scarp must be sufficiently strong to bear the pressure of the parapet above, and to present some resistance to the fire of distant artillery. It would be mere waste to give it an extra thickness, as often recommended, to resist breaching, because the breach is always ready before the descents into the ditch are completed, and the increase of outlay entailed by that extra thickness, is attended only with the trifling result of obliging the enemy to fire a few more rounds.

(321). Two sorts of revetments are employed, *solid* and *counter-arched*. The former is called a *full revetment* when the wall is carried up to the superior slope of the parapet, and a *demi revetment* when it is raised up to the level of the ground only.

Fig. 605



The full revetment is exposed to artillery from a distance, and the breach will bring down the whole parapet,* whilst the demi-revetment is not so exposed, and the breach will only bring down part of the parapet, advantages which have induced Cormontaingne and his successor to give it the preference; but many

* The small wall, 3 feet thick at the top, is called "tablette."

Fig. 606.

engineers will contend that it is an error, because the scarp is exposed to escalade, and they prefer the demi-revetment with a chemin des rondes, as possessing the advantages of both. According to its shape, the solid revetment is called leaning, rectangular, countersloping, or sloping.

Fig. 607.

The *leaning* one, the best in theory, is chiefly employed for the interior slope of the ramparts.

Fig. 608.

The *rectangular* is not now employed, because a slight sinking in the foundations brings it out of the vertical, as may be seen at St. Omer and other places.

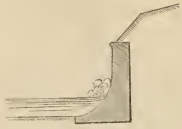
Fig. 609.

Fig. 610.

The *counter-sloping*, either with an interior slope or with steps, is not better than the sloping one when the counterslope is $\frac{6}{7}$, but becomes superior to it with a less steep slope; it is a good revetment and is preferred to others by many engineers, yet it requires more masonry.

For scarp walls exposed to the action of the sea, this profile has been recommended. At Cadiz it has answered very well.

Fig. 611.



Vauban adopted the sloping one. Before his time scarps were frequently at $\frac{3}{1}$ and $\frac{4}{1}$, because it was erroneously believed that such an inclination makes the balls glance off. Vauban made them at $\frac{5}{1}$, and Cormontaingne at $\frac{6}{1}$. It has, to a greater or less degree, the inconvenience of requiring frequent repairs; it suffers much from exposure to weather, the joints holding the wet and harbouring plants, the roots of which sooner or later destroy the masonry. Modern engineers have reduced the slope to $\frac{10}{1}$, and French engineers now adopt $\frac{8}{1}^{0}$.

For the thickness, the dimensions of Vauban, 5 feet at the top, and 5 feet $+\frac{H}{5}$ at the base, H being the height of the scarp, have not been preserved, although none of the walls he built ever gave way. It was too much for counterscarps and low walls, but it was not sufficient for very high ones. In his full revetments H was measured from the bottom of the ditch up to the terreplein of rampart, the small wall above it being only 3 feet thick. Cormontaingne gave a mean thickness of $\frac{9}{40}\frac{H}{}$; but it is now admitted that a wall, the mean thickness of which is $\frac{H}{3}$ will possess sufficient stability to resist pressure in any soil.

Belidor, Coulomb, Prony, and other engineers, have calculated formula for the thickness, which it is not our province to investigate. At present the thickness x of a rectangular wall is calculated by $x = \cdot 865\,(H + h)\,\text{Tan.}\,\frac{\alpha}{2}\sqrt{\frac{p}{p'}}$, in which H represents the height of the scarp, H that of the exterior slope, α the angle formed by the exterior slope with the vertical, p the weight of a cubic yard of earth, p' that of masonry.

For a counterscarp, $h = 0$. When the wall is sloping at $\frac{20}{1}$, the thickness at the base is $x + \frac{H}{20}$.

(322). *Counterforts*, or interior buttresses are frequently constructed to give more stability to the wall by their weight, and enable it to resist more easily the shock of distant artillery. The pressure of the earth on their interior surface is a force which also resists the forward motion of the wall. They have been made *dovetailed* (Fig. 612), *rectangular* (Fig. 613), and *diminished* (Fig. 614),

Fig. 612.

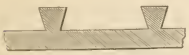


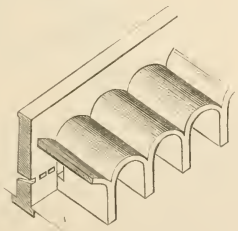
Fig. 613.

Fig. 614.

the two latter forms being preferable, because the bond of the counterfort with the wall is better established. Vauban used to place them 16 or 18 feet apart; their length, E H, was 3 feet less than the thickness of the scarp at its bottom, their width C D at root, one foot more than their length, and their tail, A B, narrower than the roots by $\frac{1}{5}$. He had not any for the counterscarps. At present the following dimensions are recommended: Length, $\frac{H}{4}$; root, $\frac{H}{5}$; tail, $\frac{2\,H}{15}$; distance, 15 to 18 feet.

(323). By constructing arches from one counterfort to the next, the thickness of the scarp may be diminished, because the whole pressure no longer bears on the front, and as the arches will support the parapet after the fall of the wall, the

Fig. 615.



breaching will be seriously hindered. The name of *hollow* or *counterarched*

revetment has been given to this disposition which is both excellent and economical, more especially for high scarps.

In the first disposition, represented with a scarp 30 feet high, the piers will be 5 feet thick, 18 feet long, and 18 feet apart from axis to axis. The arch is 3 feet thick at the top, forming a vault 21 feet high in the clear. The front wall

FIG. 616.

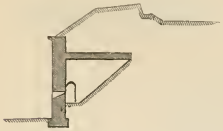


FIG. 617.

needs only be 5 or 6 feet thick. The earth falling at its natural slope, will leave an empty space to that door, being pierced through the piers, the defenders will have galleries ready made to employ mines against the breach, and loopholes being cut in the front wall, the ditch will receive a grazing fire.

In another disposition the galleries are left empty, and are closed at the back by a circular wall; they are ventilated, as shown by the diagram, and become real

FIG. 618.

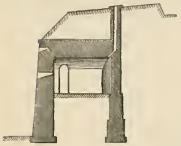


FIG. 619.

casemates. It is advisable to leave at least 4 feet of earth over the arch, to give to this a thickness at least equal to $\frac{1}{3}$ the radius of curvature, and to pierce the loophooles at equal intervals measured on the outside, because the enemy cannot guess at the very place of the piers, and thereby breach more easily.

Another system of hollow revetment has been constructed with a second wall behind the first, the arches being parallel, instead of perpendicular to the front; but the pressure of the vaults bears on the front, and renders breaching less difficult.

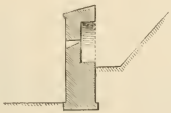
Fig. 620.

(324). The *independent* scarp wall consists of a wall 3 feet thick erected at the foot of the exterior slope, and when it is breached the parapet cannot fall.

Fig. 621.

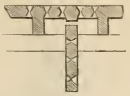
It is loopholed and provided with a banquette. Sometimes it is arched in the rear to cover the men from enfilade, and to gain additional strength. The height

Fig. 622.



should not be under 20 feet. It is often seen in Germany, where the advantage claimed is, that it is less exposed to escalade than other revetments of greater height, since the enemy, arrived at the top, will require fresh ladders to descend. This chemin-des-rondes is greatly improved by the construction of traverses placed at intervals of 50 or 60 yards; their loopholes enable the defenders to fire at the salient, and as they join the covering mass, they prevent the enemy lodged at the salient to enfilade and plunge the whole.

Fig. 623.



(325). With regard to the *foundations*, Vauban used to make them 3 feet deep, with a retreat of $1\frac{1}{2}$ feet in good soil, but these dimensions must be increased whenever the soil is compressible. At Ypres, for instance, some foundations were made 17 feet deep. Sometimes to prevent the revetment from sliding outwards piles of wood have been buried or spurs of masonry built at the foot of the foundations.

Fig. 624.

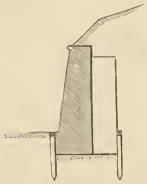
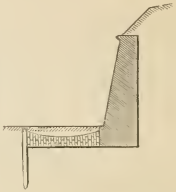
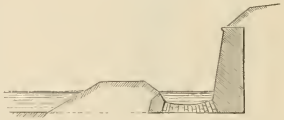


Fig. 625.



In aquatic sites, where ditches are usually very large, a mass of earth may be advantageously left before the foot of the escarp to serve as a prop to the spurs of masonry.

Fig 626.



SECTION V.—Of the Ditch.

(326). The *ditch* is destined both to form a serious obstacle to the further progress of the besieger, and to furnish the deblais for the construction of the rampart and parapet.

The greater its width and depth, the greater the obstacle; but reasons of economy and the necessity of equalising the deblais and remblais impose limits.

In general, the width at the salient of the bastion is 30 yards. At that point the counterscarp is traced on the arc described from the salient of the escarp as centre, and it is afterwards fixed so as to admit of a sight of the ditch from the whole flank, the width thereby increasing from the salient to the curtain, unless the flank be less than 30 yards, in which case the counterscarp is better traced parallel to the magistral.

It is preferable to increase the depth of the ditch rather than its width, because by this the enemy is delayed longer in constructing his descent gallery. Some engineers recommend it to be made narrow and very deep for that reason, and also because when the depth is such that the batteries established on the crowning of the covered way do not afford a view of two-thirds of the escarp, the besieger is obliged to erect his breaching batteries in the covered way itself, or to have recourse to the mine, two dangerous and uncertain operations; but narrow ditches have the serious inconvenience of being liable to be filled by the debris of breaches made at the escarp and counterscarp. Therefore, these are not made less wide than 25 or 20 yards. That of the ravelin may vary from 15 to 13 yards.

When the width is settled, the depth is found by the conditions of the deblais, and we have seen that it should be such as to leave at least 30 feet to the revetment of the escarp.

The counterscarp should always be revetted; it would not otherwise be a serious obstacle, and the higher the better; but some reasons of economy not unfrequently oblige the revetment to be made as low as possible, viz., 15 feet. When the terreplein of the covered way, the position of which is determined by special considerations (Sec. I. Chap. XXII.), is more than 15 feet above the bottom of the ditch, the revetment may be maintained at 15 feet, either by making the ditch slant towards the escarp, or, what is better, by joining the masonry to the terreplein by a slope.

(327). In order to carry off the water arising from springs or rains, it is usual to give to the bottom of the ditch a slope, both from the escarp and the counterscarp to the middle, where a small ditch, 4 feet wide at the top, 2 feet at the bottom, and 3 feet deep, called *cunette*, is excavated. When there is much water the cunette may be made larger and deeper, and it forms a fresh obstacle. It should have a sufficient fall to drain the ditch off to a well sunk for the purpose, or to some low ground away from the fortifications.

CHAPTER XXI.

ADDITIONAL WORKS.

SECTION I.—Outworks.

It is a general rule that all the outworks constructed on a front should be flanked by the enceinte itself, that their gorge should be open, that their terreplein present no cover for the enemy, and that their combination be such as to admit of a successive defence.

(328). The *ravelin* is most frequently employed, although it by no means forms an indispensable part of a front, especially in uneven ground. The effectiveness of that work increases with its saliency, but not indefinitely, because its breach must be defended by the bastion within easy range, and with a great saliency the enemy can breach the enceinte from a greater distance. For these reasons it is advisable to limit to 200 yards, the maximum distance from its salient to the crests of the enceinte. The flanked angle will be 60°, the minimum, because a larger angle would bring the re-entering places of arms too forward, and the glacis of the ravelin would not be well flanked by the faces of the bastion. This last consideration necessitates a further reduction of the saliency when the bastions are small, because it is desirable that 50 yards at least of their faces should not be masked. Several engineers have greatly modified this outwork, especially with the view of closing the opening of its ditch on the enceinte; and we shall examine their construction further on. At present we confine ourselves to the ravelin of the ordinary bastioned front, such as we find it in the modern system.

Some engineers object to this ravelin, that the narrowness of its terreplein leaves no room for the employment of mines in the defence, and renders offensive returns very difficult, whilst the besieger can find sufficient space to construct his batteries.

Although an unrevetted ravelin answers all the requisites of exterior defence, yet it is better to revet its scarp, because the enemy being obliged to enter by a

breach, the defenders will find it easier to repulse the assault. The scarp need not be so high as the enceinte, and its minimum may be fixed at 15 feet. The ditch, from 12 to 20 yards wide, slopes towards the main ditch to carry the water off, and at the same time exposes itself to views from the bastion. The command of the curtain on this work should not be less than 3 feet.

(329). The gorge of the ravelin may be organized so as to form a sort of retrenchment from which the garrison can make offensive returns, and oppose an extended line to the necessarily narrow front of the enemy, but it is preferable to construct a *reduit* on the principle of the modern system. The faces are kept parallel to those of the ravelin, and the flanks are made 20 yards long. A revetted escarp of 15 feet is necessary, but the counterscarp is better left unrevetted, and even sloping as a ramp towards the salient, to enable the defenders easily to attack the lodgment of the besieger. The width at the bottom of the ditch may vary from 12 to 15 feet. This outwork should possess a sufficient command over the ravelin to enable the men to fire over it on the glacis of the collateral bastions; but as this command might cover the terreplein of the ravelin from the view of the enceinte, it will be proper to adopt a command of $1\frac{1}{2}$ feet only. The magistral is kept in a plane with the terreplein of the ravelin, and the interior of the work is maintained as low as conveniently can be.

The saliency of the reduit must be sufficient to enable the faces of the bastions to flank its ditch, which is generally 12 or 15 feet above that of the ravelin.

Masks of earth, in the shape of a glacis, are erected both in the ditch of the ravelin, and in that of the reduit to close the troués; they are placed near their gorge, and are kept at such a height as will prevent the escarp from being breached.

(330). *Coupures* along the faces of the ravelin prevent the enemy from turning the re-entering places of arms of the covered way, defend the breach of ravelin, permit offensive returns, and secure the retreat of the defenders; therefore, they are frequently adopted, although their ditch is only flanked by the reduit. Their command is the same as that of the reduit; their ditch, about 12 feet above that of

FIG. 627.

this work, will slope towards the escarp of the ravelin; the escarp, about 12 feet

high, and the counterscarp not less than 9 feet, should be revetted. When the depth of the ditch of the ravelin is such that there remain 15 feet of escarp, it is better not to close the ditch of the coupure, as it is done in the modern system. It must be borne in mind that the enemy established at the salient of the covered way of the ravelin can see the interior of the coupure near the gorge.

Coupures may occasionally be made in the reduits themselves.

In Germany we find ravelins that, instead of the redoubts of Cormontaingne, are provided with bomb-proof block-houses or buildings having casemates for artillery, and loopholes for musketry.

Fig. 628.

A loopholed wall connects them with the gorge of the ravelin, and a ditch prevents the enemy from approaching. Prussian engineers deem it impossible for the besieger to establish batteries against this retrenchment, and they adopt a similar disposition for bastions.

(331). The *tenaille* is an accessory that may be dispensed with when there is no outwork between the enceinte and the glacis, and replaced by a traverse of earth masking the postern. In a complete front, its properties re-appear, but its relief must allow to the whole flank a sight of the foot of the escarp of the bastions. At present it is no longer revetted except at the wings. The form of the modern system is generally the best, but there is still a dead space along the flanks.

(332). *Counterguards* or *Couvre-faces* are thrown up before the bastions or ravelins, as we have seen in the second and third systems of Vauban. Sometimes they have a narrow terreplein, and are either scarped with masonry, or are entirely of earth.

Fig. 629.

Vauban gave a great thickness to his counterguards, whilst other engineers—

Cormontaingne, Bousmard, Carnot, &c.—made them very narrow, to prevent the besiegers from availing themselves of their terreplein, and constructing breaching batteries on it. Experience, however, decidedly pronounces in favour of Vauban's ideas, who recommended not to assault these works, but to destroy their parapets, in order to permit the breaching batteries of the covered way to batter down the enceinte. If the counterguards are employed as a mask to cover the enceinte, a great thickness is certainly desirable, and the besiegers would not save time in assaulting them for the purpose of constructing new batteries in their terreplein.

At the siege of Landau, in 1703, Marshal Tallard lost time in assaulting the counterguards, and was thereby obliged to encounter the Count de Nassau; and had he not succeeded in beating him at Spire, the consequences would have been most disastrous; whilst the breaches to the enceinte could have been made at once, by merely giving an extra relief of 3 feet to the batteries of the covered way.

At Turin, in 1706, La Feuillade made the same mistake, and not only lost the place, but was beaten by Prince Eugene.

A similar mistake of carrying successively every enceinte, whilst they could be simultaneously breached, was made by Wellington at Burgos in 1812, and he was compelled to retire after five murderous assaults.

Counterguards are not so frequently constructed at present as they used to be. Whenever employed, either before a bastion or a ravelin, they should completely cover the masonry and never hinder the fire of these works, conditions which have not always been fulfilled. They are found in old fortresses chiefly before bastions, deriving their flank defence from the ravelins or from their reduits.

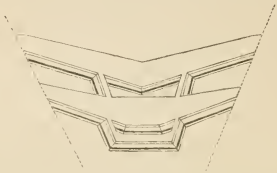
Fig. 630.

They diminish the depth of the re-entering space between the ravelins, so that the enemy can crown simultaneously the salients of the ravelins and of the bastion. Their long faces being exposed to ricochet, they are untenable by the defenders, and their ditches as well as those of the ravelins become dead, the covered way is abandoned to its own resources, for the enceinte can hardly fire over the counter-

guard, and the combination of command between these works renders the construction of a redoubt of re-entering place of arms very difficult. The shoulder angle of the redoubt of ravelin, can be breached through the ditch of the counterguard, and it may be stormed at the same time as the ravelin. All these inconveniences, added to the great outlay they occasion, have not a little contributed to throw counterguards into discredit. Nevertheless, when old fortresses, the masonry of which is generally exposed, are repaired, counterguards are found to answer well, as they are cheaper than the work required for raising the counterscarp, the covered way, and the glacis.

Sometimes they are constructed on a better principle, as in the following disposition called a *front of counterguards*, where they mutually flank each other, but the

Fig. 631.



best disposition would be that in which they are flanked by the enceinte itself, and this is only possible in certain localities. Several engineers have recommended counterguards in preference to ravelins, but Vauban and Cormontaingne, decidedly object to them; however, it must be confessed that in their time, the counterguards in use were very bad, scarcely covering more than half the length of the faces. They have important advantages, inasmuch as the enceinte being protected the enemy must occupy them before breaching the bastion, and they detain the enemy longer than ravelins would. On the other hand, they do not give a cross fire on the capital of the bastions, and the enceinte being unable to fire over them, there is not so great a development of fire against the attacks; it is difficult to flank them, and to organize good retrenchments in them. French engineers seem to prefer them to ravelins, and they form coupures on the terreplcins to defend the salients; a redoubt of re-entering place of arms is also constructed to fire on the collateral capitals. Both counterguards and ravelins are seldom used together, except in places of importance.

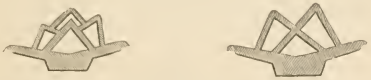
Counterguards have occasionally been placed before ravelins, especially when these were small. If the ravelins are large, the advantages gained are not a compensation for the distant, and therefore inefficient flanking of the glacis, of the salient place of arms, and of the salient of the counterguard itself.

The name of *envelope* has been given to the continuous enceinte, formed when the counterguards of the bastions are joined to those of the ravelins; it may increase the length of the defence, but coupures must be made to prevent the enemy from spreading, and a strong *armament* should be given.

To conclude these remaks, we may add that, when counterguards cover the masonry, the glacis may be greatly simplified. It causes a serious outlay, which can be reduced by giving the minimum command to the covered way, the terreplein of which may be below the level of the country. The glacis, still seen by the enceinte, is thus made very small.

(333). *Tenaillons* and Demi-Tenaillons are employed to strengthen the small ravelins of the old tracings.

Fig. 632.



Those works by increasing the saliency of the ravelins, had the advantage of compelling the besieger to carry two ravelins before attacking a bastion, but their cost is great compared to that of a counterguard, and they are no longer constructed in modern fortifications.

(334). Formerly, *hornworks* were in high repute, and might be seen in almost every fortress; they were sometimes erected to excess, and yet, such as they were, they had but little value.

Fig. 633.

The long branches are exposed to ricochet; the front, being narrow, is easily enveloped and silenced, and the ditches permit the besieger to breach both bastions. Vauban certainly made an improvement by constructing the hornwork before the bastion, because the enemy is thus compelled to carry the two collateral ravelins,

Fig. 634.

and erect the breaching batteries in the terreplein of the work itself, and then he

will only be able to breach one bastion. On the other hand, the long branches are still enfiladed, and the ravelins that flank their ditches require to be garrisoned, since the enceinte cannot fire into them.

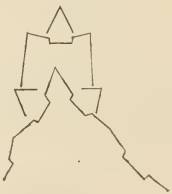
In both cases, the long branches have the great inconvenience of masking the fire of the collateral works, thereby allowing the enemy to proceed with comparative safety into the spacious terreplein. Again, unless the ground be especially favourable, the command of these works does not permit the men on the bastions to fire over them, and part of the enceinte does not command the country; they require an increase of garrison, an inconvenience which ravelins or other outworks flanked by the enceinte do not entail. And, lastly, they occasion great outlay.

They should not, therefore, be indiscriminately employed as they have been, and the addition of coupures, which increase the cost without adding to the value, such as are here represented, should be set aside.

Fig. 635.

In general, and despite all the inconveniences which we have enumerated, a hornwork cannot be replaced by any other work when protection is required for a bastion forming a salient. They are excellent for enclosing suburbs, and

Fig. 636.



forming tetes-de-pont. Their spacious terreplein, too, is useful to construct military buildings on.

When constructed, the front should, as much as possible, have the same dimension as that of the enceinte: the escarps should be higher than those of ordinary outworks, about 20 feet, although those of the branches may be only

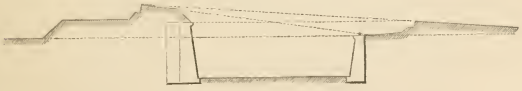
15 feet. Ravelins or counterguards may be added, but this accumulation of works will rarely give an increase of strength proportionate to the outlay.

Crownworks are employed for the same purpose as hornworks, and all we have said about these is applicable also to them. Both require a covered way.

Fig. 637.

(335). The *covered way* is an outwork, which can never be dispensed with, unless the fortification stands in front of an impracticable marsh or on an inaccessible rock. It has been successively improved by Vauban and Cormontaingne, but its essential property—that of enabling the garrison to go the rounds and assemble in safety before and after sorties—must not be overlooked. The construction of a banquette to give musketry fire on the glacis, that of a re-entering place of arms to support the defenders in the branches of the covered way, and that of traverses to resist ricochet are excellent improvements, but these should not cause us to overlook the fundamental property. The traverses, for instance, render the communications along the covered way difficult, not to say dangerous; and nothing has yet been devised to remedy this. The terreplein was originally on the ground itself, or a little below, so that the crest had a small command, quite insufficient to conceal the masonry of the escarp. Cormontaingne was the first engineer to introduce the rule that the crest of the glacis must cover the masonry: the increase of command which it implies occasions very great remblais, and in order to diminish them, 3 feet of the escarp may be left uncovered, since it will not endanger it. At present the covered way is constructed so as to give a command of 8 feet to its crests, covering the masonry, and to allow at least 15 feet command over them to the parapet of the enceinte: these parapets should also

Fig. 638.

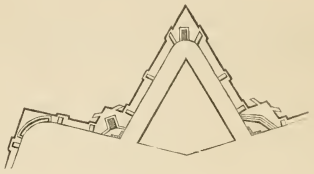


present a view of the top of the counterscarp, or at least of a point 3 feet above it. The ditch of the ravelin being narrower than that of the enceinte, the command of the ravelin over the crest of the glacis cannot exceed 5 or 6 feet. Both the covered way of the bastion, and that of the ravelin, should be commanded by the re-entering places of arms.

The glacis should be exposed to a grazing fire of musketry from the crest of the covered way, as well as to a musketry or artillery fire, either direct or reverse, of the works in rear. Their prolongation must, therefore, pass 3 feet below those crests when armed with artillery, or through the crests themselves when only defended by musketry. Their surface should as much as possible be plain, and salient edges or deep gutters should be carefully avoided. An excellent disposition, adopted in Germany, consists in planting the glacis with trees: these being cut down during the first period of the siege furnish timber, whilst the roots form a serious obstacle to the progress of the saps. When the ground sinks in front, it is often advisable to avoid the remblais necessary to complete the glacis, and to terminate it by a slope, forming what is called a "*glacis coupé:*" this slope should be exposed to flank and reverse fire. In general the inclination of the glacis is $\frac{1}{3\cdot4}$, but it may vary from $\frac{1}{4\cdot6}$ to $\frac{1}{16}$, and even be steeper, provided it is seen by the defence, inasmuch as the construction of the sap, trench cavaliers, &c., is rendered difficult.

The *redoubts of places of arms* are usually constructed during the siege, but in important fortresses a permanent organization is preferable. They may be erected in salients as well as in re-entering places of arms. A loopholed wall

Fig. 639.



run across the terreplein will answer the purpose, if nothing better can be done. A solid block-house connected to the counterscarp by a stockade, and preceded by a small ditch, called "diamond" in Germany, is frequently found in that country. The best redoubt is formed of a revetted parapet, such as that of the modern system. The redoubt should leave 10 yards of terreplein to the place of arms, and be preceded by a small ditch of 12 to 15 feet, which, however, should not indent the counterscarp so as to leave less than 15 feet of masonry above the bottom of the main or ravelin ditch. Its relief should not mask the fire of the work in rear, and yet it must be such as to afford a sight of the glacis. Many engineers recommend the construction of a loopholed gallery behind their escarp, from which the terreplein of the place of arms may be fired on.

The redoubt of the re-entering place of arms should derive its defence from the bastion and from the redoubt of the ravelin, and at the same time its terreplein should be defiladed from the salient of the ravelin itself, otherwise the besieger may turn it. In this respect, the redoubt of the modern system is defective, since it cannot be defended when the besieger has taken the ravelin.

SECTION II.—Advanced Works.

(336). *Advanced works* are those placed beyond the glacis, but near enough to receive protection from the body of the place. They are designed to oblige the enemy to commence operations at a greater distance, to defend certain parts of ground which cannot be seen from the parapets of the front, to cover a bridge, a sluice, or a dam, which it is essential to preserve, and to increase the number of assaults the besieger has to give before attacking the enceinte. They have, however, serious disadvantages: they derive but a weak protection from the place, and are exposed to attacks of vive force; they require a special garrison, and once occupied by the enemy become advantageous to him for the construction of his trenches. As a rule, they are not constructed for small fortresses, and when employed they should not be further off from the enceinte or the outworks than 400 yards.

(337). *Lunettes.* Modern engineers have proposed to construct these before all the salients, so as to form a sort of line with intervals, but their ideas have not found favour, because such works are exposed to simultaneous attacks; they subdivide the garrison, and weaken the energy of the defence. They are now constructed only on the capital of some bastion, and flanked by the collateral ravelins. Their salient angle cannot be more than 60° or 70°, because the faces must be at right angles ornearly so with those of the ravelins. It is usual to give 60 yards to their faces and 20 yards to their flanks; these are directed so as to defend

Fig. 640.

either the salient or the gorge of the next lunette. In order to prevent the enemy from erecting batteries in them, the rampart is but 10 yards wide, and their terre-plein is cut by a ditch with a stockade forming a reduit. The crest of the parapet

Fig. 641.

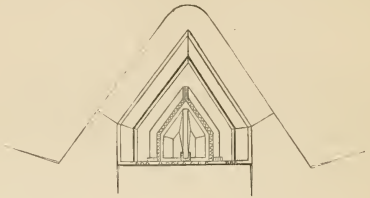
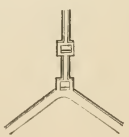


Fig. 642.

should be in the same plane with that of the glacis, or not more than 3 feet above it, otherwise the enemy might plunge in the covered way of the ravelin; this small command exposes the lunette to be turned in the rear, and to avoid this danger the gorge is occupied by a wall 15 feet high, 3 feet thick, and provided with two rows of loopholes. There is no need of a covered way, inasmuch as it would lower the counterscarp, expose the escarp, and facilitate the attack by vive force. The ditch may be 30 or 40 feet wide, the escarp and counterscarp 20 feet high, and the crest of the glacis 6 feet below that of the lunette; this ditch is excavated in ramp as we have seen in the lines with intervals, to expose it to the fire of the ravelins.

Communication is established between the lunette and the place by a gallery opening in the counterscarp of the salient of the bastion, and in the reduit of the lunette; from the reduit to the rampart the defenders communicate by two small moveable bridges. When it is not possible to make such a gallery, a double

Fig. 643.



caponier with traverses must be erected, which is a serious inconvenience, since it forms a sap ready made for the besieger.

Fig. 644.

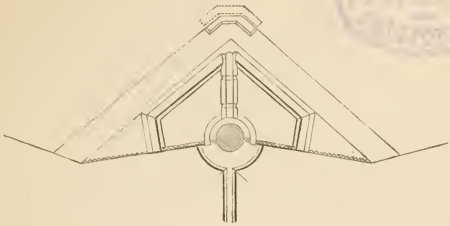
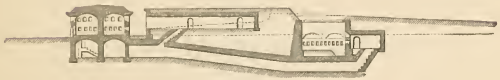


Fig. 645.



(338). *Lunettes d'Arçon.* In order to bring the lunettes further off the place and diminish the defect of their gorge, General D'Arçon has constructed at Besançon, Metz, and other places, lunettes which bear his name, and which are supposed to be capable of defending themselves. This work has the same dimensions as an ordinary lunette, except that the salient angle may be made as open as deemed necessary. The gorge is closed by a loopholed wall 18 feet high, and a round tower 15 feet in diameter separated from the terreplein by a ditch 12 feet wide. The masonry of this tower is masked by the parapet of the lunette, and the top is covered by 3 feet of earth. Large openings under the cornice give a free egress to the smoke, and serve as machicoulis for the defence of the foot of the tower: the loopholes are 6 feet above ground. A lower story leads to a reverse casemate constructed under the glacis at the salient of the counterscarp for the defence of the ditch.

A bomb-proof traverse divides the terreplein of the lunette into two, protecting it from reverse fire: it is vaulted and opens into the ditch of the tower from whence it receives light; four doors establish communication between it and the two moieties of the lunette. The ceiling of the gallery leading to the casemate is pierced to receive a moveable staircase leading to steps ascending to the vault: this opening can be strongly closed after the retreat of the defenders.

The circumference of the tower touches only the line of gorge, and the wall is directed towards its centre to receive a little flank defence: circular ramps lead from the ditch of the tower to the terreplein of the lunette, and strong barriers prevent the passage of the enemy. A double caponier, well palisaded, connects a door in the tower to the place.

The lunette D'Arçon does not seem likely to stand the attack by vive force: the "réduit of sureté," the name given to the tower, and intended by D'Arçon to facilitate offensive returns, would soon be destroyed by vertical fire or even by direct fire aimed at the extremities of the flanks, which are weak points. The loopholes of the reverse casemate may be rendered useless by throwing fascines into the ditch, and as the flanks have no defence, the enemy once in the ditch will escalade them easily and surround the tower, and the defenders will retire to the rear, when the lunette is taken before any use has been made of the reduit. Baron Maurice, a Swiss engineer, has proposed a modification of this construction which the figs. 646, 647, will at once render intelligible: the top of the tower is

Fig. 646.

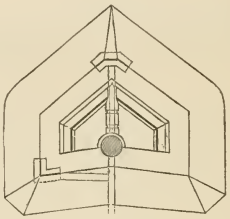
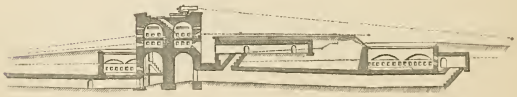


Fig. 647.



destined to receive artillery to fire before the glacis; the ditch and glacis altogether enclose the work: at the gorge the ditch is flanked by the tower as well as by a little casemate. A gallery passes from the tower to the place, and serves for the retreat to the defenders. The masonry of the tower is still more exposed to the artillery of the enemy; the communication to the rear is safer than the caponier, but D'Arçon had a gallery in his lunette at Metz, and it is an improvement which

cannot be made on every kind of ground; the defects of the work remain very nearly the same, and the simple lunettes of the form we have described are decidedly preferred by the majority of engineers.

(339). A *fleche* is the name given to a little redan placed at the foot of the glacis of a bastion or a re-entering place of arms: it is a work much inferior to the lunette, and is only erected when there is an advanced ditch to defend; it communicates with the rear by means of a double caponier.

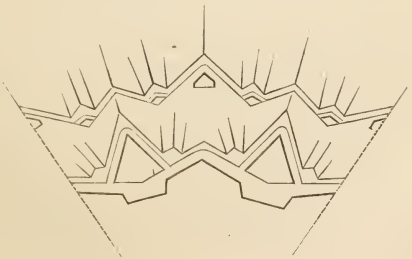
(340). *Horn-works* are decidedly better than lunettes, because their front flanks itself, and at the distance at which they are erected this front can receive good dimensions, and their branches be directed towards the outworks which will flank them best. To occupy a hillock or a little valley in front of the place, they are excellent. *Crown-works* answer the same purpose when the ground to be covered is wider. Their gorge is closed as for lunettes. French engineers frequently construct crown-works.

(341). An *advanced ditch* is formed by the prolongation of the glacis. An *advanced covered way* is a covered way on the exterior of an advanced ditch.

FIG. 648.

This work is never constructed on the whole perimeter of a fortress, because the increase of defence is not worth the immense outlay which it necessitates. It is employed only on some particular parts, for instance, to occupy the edge of a steep slope which cannot be seen from the place, or to give safe access beyond an inunda-

FIG. 649.



tion. The flanks should rest on good obstacles. It serves only for the exterior defence of the place by the outposts whilst the enemy is still far off. It becomes better when it is supported by advanced lunettes, especially before fronts in straight line. Whenever employed, there should be at least 60 yards of interior glacis, the counterscarp should be revetted, the re-entering places of arms provided with small redoubts, and the crest kept below that of the interior covered way. Communication is established by a caponier between the branches of the covered way of the ravelin and the little redoubts. The lunettes preserve their own communications.

SECTION III.—Detached Works.

(342). *Detached works* are the works constructed at a distance, more or less great, from a fortress, deriving their defence from themselves and designed to occupy important positions, to render the investment more extensive and therefore more difficult, to defend the approach of the most accessible fronts, and to preserve to the garrison the use of the country even after the beginning of the attacks. They generally consist of isolated forts, often of some importance, as at Lyons and Paris, and of redoubts, lunettes, towers, &c.

As the relief must be sufficiently great to prevent escalade, the small extent of the fronts of these forts becomes an obstacle to the condition of self-defence, the ditches being mostly dead. Several means have, therefore, been employed to remedy this, as loopholed scarp walls, machicoulis, galleries of reverse, and bastionets.

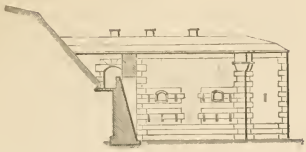
(343). The *loopholed scarp walls* weaken the revetment (374), always leave a dead angle at their foot, require many men to survey the ditch, and are only employed when nothing else can be done. The loopholes have no action on the exterior, because they are placed rather too low to be defiladed from the fire of artillery. Towers are almost the only works to which a defence based on loopholes is applicable.

(344). *Machicoulis* leave no dead angle at the foot of the escarp, and are out of reach of the enemy when he has entered the ditch, but they are expensive and exposed to a plunging fire of artillery, which is all the more dangerous from their masonry being usually weak. They are not better than loopholes, and only applicable to towers and barracks covered from the fire of artillery.

(345). The *galleries of reverse* are better, and both French and Germans have frequently constructed them, but they should only be considered as an accessory means; otherwise, the garrison, already small, is further reduced, and the defence becomes less energetic; the loopholes may be rendered useless by means of fascines, or the gallery itself may be destroyed, the ditch losing its defence even before the breach is made.

(346). *Bastionets*, or small bastions in masonry, either casemated or open, and

Fig. 650.



placed at the salients of a work, are still better. When casemated, the masonry should be covered by the glacis. In the open ones, the defenders are more exposed, for if they do not stand exposed to a plunging fire from the counterscarp, they suffer heavily in a narrow terreplein from vertical fire: on account of this, open bastionets are placed at those salients only which the enemy is not likely to attack.

(347). The outline of detached works varies indefinitely, almost every form having been adopted. At Lyons, some forts have the shape of a trapezoid, the large base being towards the place, and this form is preferable to a regular polygon, because the angles exposed to attack are thus rendered more obtuse. The gorge of all those works should be closed, as in advanced lunettes, by a wall of the bastion form and a ditch. The covered way will usually be dispensed with, since the small garrison cannot spare many men for its guard, and it will be constructed only to give views on such grounds as cannot be seen from the parapet. The further these works are from the place, the stronger they should be: the height of their escarp must increase, and when the distance is such that their garrison will probably be obliged to sojourn several days, defensive barracks are built generally near the gorge.

When the position occupied is very important, the work becomes a small fortress, which may have ravelins, counterguards, covered way, &c.

It is considered necessary to construct reduits in detached forts to prolong their resistance, either by imparting confidence to the garrison, or by actually participating in the defence. According to the importance of the fort, the reduit may be a tower, a defensive barrack, a redoubt with bastionets, &c.

(348). We shall have an opportunity of speaking of the detached works constructed in Germany, but we cannot leave this subject without alluding to the nature of the works now in course of construction in England, because, though they bear some resemblance to the German tracing, their construction is far better, and contains many of the improvements which have been proposed by the

advocates of the bastion tracing. Without in any way setting aside the bastion tracing, the English engineers entrusted with the defence of dockyards, &c., prefer the polygonal tracing for detached works, because the size of these works would not permit the construction of properly developed bastions, the interior space would be too limited, and the faces of the bastions could not bend themselves so well to the ground, or bring their fire simultaneously on the direction required. We speak of these works as specimens of detached forts, but avoid entering into the discussion of the value of the combination made with them for the defence of the approaches of Portsmouth. If taken in their ensemble, the system may be severely criticised as not answering the purpose in view, yet *taken singly*, these forts are constructed on decidedly superior principles. The figures represent the nature of the works in the neighbourhood of Gosport.

Fig. 651.

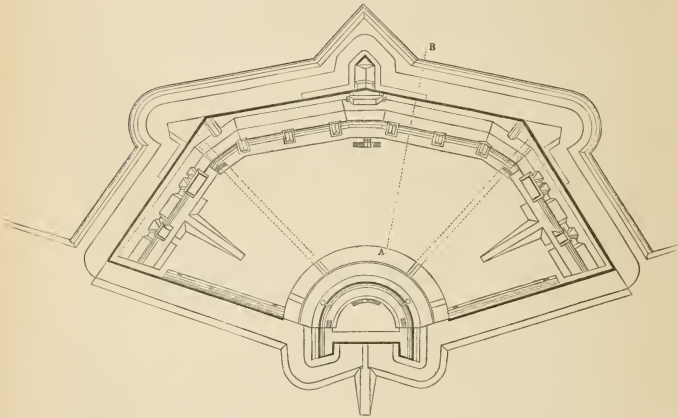
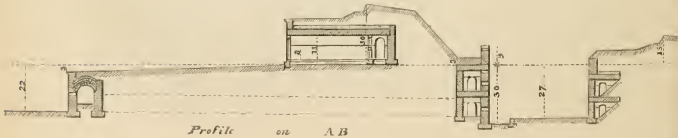


Fig. 652.



The angles are made obtuse to permit one face to take up the fire of the adjacent one. The ramparts of the faces are protected from ricochet by traverses, either solid or hollow, to serve as expense magazines, and those of the flanks which are more exposed to enfilade by traverses casemated à l'Haxo. The parapet does not invariably run parallel to the ditch, whose escarp and counterscarp are traced independently of the rampart whenever desirable.

The ditches are flanked by caponiers hidden by the counterscarp, and so constructed as not to be exposed to destruction by any battery erected in the prolongation of the faces. They are for musketry and artillery, to permit the

Fig. 653.

Section through Mortar Battery and Central Caponier.

use of canister and grape. At the salient of the rampart there is a casemated battery for mortars (*see* Sec. II. Chap. XXIV.)

The command of the works is regulated so as to sweep the ground in front, and to allow the construction of bombproof casemates under the rampart of the faces. These casemates form excellent barracks for the garrison: they are connected in front by a gallery of communication, which is lighted by vertical shafts pierced through the rampart, which also insure ventilation. The parapet is made 24 feet thick for the faces, and 20 for the flanks. The ditch is narrow, 45 feet, and the escarp, 30 feet high from the bottom to the foot of the exterior slope, is thereby protected from distant fire. A chemin des rondes runs along the foot of the exterior slope, and has for parapet a loopholed wall 7 feet high, which makes up a total height of 37 feet for the escarp. The top of that wall is 6 feet below the crest of the glacis along the faces, and 3 feet along the flanks. Its fall does not endanger the escarp. The chemin des rondes gives facilities for repairing the parapet, which the enemy may have destroyed, and cannot give a footing to an assaulting party, because it is flanked by galleries at the angles. The revetments of escarp and counterscarp are made "en décharge."

The gorge is occupied by a casemated keep, either polygonal or circular, that will enable a comparatively small number of men to defend the work. A circular keep, containing accommodation for 100 men, is now in course of erection at Brockhurst Fort. It commands the whole terreplein, and sufficiently

Fig. 654.

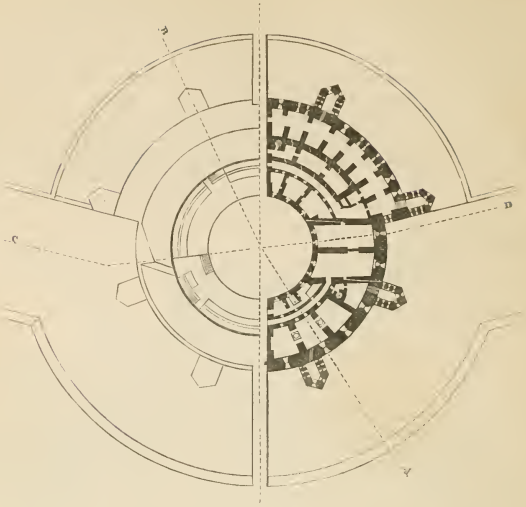
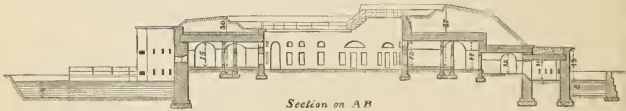


Fig. 655.



Section on AB

Fig. 656.

Section on C D

projects to the rear to flank the ditch of the gorge, and to afford an artillery fire difficult to silence along the crest of the glacis of the collateral forts. It has two tiers of guns, the upper on the terreplein, the lower in the casemates. These casemates are constructed *en décharge*, and their wall towards the front is kept as much as possible below the crest of the parapet of the work, but not so as to prevent the guns from sweeping the terreplein; it is thereby less exposed to being breached. As for the crest of the keep, it has a sufficient command over the parapet of the fort to fire at distant batteries, but not to sweep the glacis. The ditch is flanked either by a musketry caponier, as in this case, or by a counterscarp gallery, from which a subterranean communication leads to the caponiers of the work.

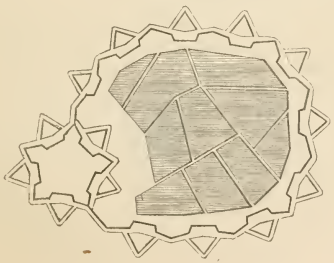
The gorge of the forts is closed by a wall, with a ditch and counterscarp connecting the keep with the inner extremities of the flanks: it has an earthen banquette on its rear, and is made sufficiently strong to resist a stray shot that might pass over the parapets.

These forts are constructed about a mile apart, and are not connected by lines; but it has been proposed to close the interval between them by a wall 18 feet feet high concealed in a ditch.

(349). *Citadels* are small forts erected in the most inaccessible part of a fortress. They are intended either to serve as a refuge for the garrison, in order to prolong the defence after the place has fallen, to command a place recently conquered, or to occupy the key of the position when the place being weakly garrisoned or badly fortified, it is advisable to let the enemy occupy the town and to defend only the citadel.

In the first case it consists of a fort with 4, 5, or 6 fronts sufficiently large to accommodate ⅓ths of the whole garrison, it is best constructed on the circumference of the place, to be enabled to receive the re-inforcements that may arrive, but the

Fig. 657.



fronts on the exterior must be very strong, and those facing the town weaker, otherwise, the enemy will at once besiege the citadel, to avoid a double siege. An open space called *esplanade* is left between the town and the glacis of the citadel, to prevent the enemy from making his approaches under cover. The escarp of the place should join that of the citadel so as to leave no 'trouée,' and at the same time, so as not to mask the flanking; the junction can therefore be made with the salient of a bastion, either by a kind of a batardeau or by a narrow branch. Sometimes the citadel may be detached from the enceinte on a commanding point, but the fortifications of the place should not be interrupted, and as regular attacks cannot be carried between the citadel and the place, this part of the enceinte may consist of a mere gorge.

The second case is now of very rare occurrence; the dungeons and castles of the middle ages were citadels of this kind: the populations often hostile to the garrison, were kept in obedience by them; should such a citadel be necessary, it will consist of a regular front placed on the circumference.

In the third case, the citadel is the principal work, and requires to be made strong in proportion as the place is weak; it may be constructed for open towns, the approaches and interior of which may thus be commanded and rendered unfit for the enemy.

Many engineers object to the construction of citadels as being anti-national, useless for the defence and even dangerous. They contend that populations are now more patriotic than in the past, and will share with the garrison in the defence, whilst the sight of a citadel engenders apprehension among them; that the garrison will be too crowded in a citadel and too exhausted after a first siege to support a second; and that the possession of a citadel renders the enemy more exacting towards the town. However, the majority of engineers recommend them, because if they are not called into play, they nevertheless act morally and impart great confidence to the garrison.

(350). *Intrenched Camps* before fortresses were proposed by Vauban in 1696. He had found that towns were too confined in space to receive garrisons of any importance, and as it often happened that armies were compelled to seek a momentary refuge against a superior foe without intending to abandon the country entrusted to their defence, he provided for it by constructing intrenched camps around the places. It was thus that he erected those of Dunkirk, Ath, Namur, and Lauterburg. This camp serves as a barrier against invasion, extends the defences of the fortress, allows the besieged to refuse battle without losing ground, offers safe magazines, affords shelter to a defeated army, serves as a place of security for materials, cattle, and forage, and by its great development and resources compels the enemy to attack it regularly. The Marquis de Feuquières, in his Memoires, gives long rules for the selection, establishment, &c., of intrenched camps, and mentions those of Utrecht, Brissach, Liège, &c.

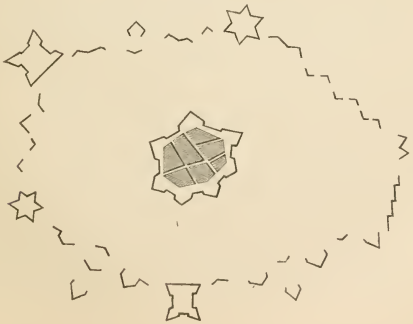
The intrenchments which surrounded them were at first continued lines, and it

Fig 658.

is only at a later period that a positive advantage was derived from these camps, by defending them with detached works which allow the troops to assume, at a moment's notice, the offensive or defensive. In fact, this improvement was most necessary: in his Memoirs, Frederick the Great, when speaking of the camp of Pirna, said that if it were difficult to carry it, it was not less difficult for the defenders to leave it, and he preferred making use of lines of redoubts disposed on salient and re-entering angles, a method that had already been adopted by Marshall de Saxe, at Maestricht, in 1748.

The camp which Frederic intrenched at Bunzelwitz, contained 40,000 men, it was traced and executed in five days, and the allies could not force it.

Fig. 659.



At the present day, engineers do not entirely agree as to the precise form and nature of these camps; their necessity has been admitted, but their modes of construction differ, and every country adopts a particular system for itself.

Setting aside for the present the German methods, we may say that in general, an intrenched camp consists of lines with intervals supported by forts; if at a small distance from the fortress, it is not exposed to be taken with it. Such works cannot be constructed before hand, because they would entail too heavy an expense on the State.

SECTION IV.—Coast Batteries.

(351). Coast batteries are generally constructed at the extremities of capes, necks of land, &c., as near as possible to the sea, so as to enfilade the lines of approach (434).

They are traced perpendicularly to the direction in which they have to fire, but if the ships can approach in several directions, instead of adopting a circular tracing, which does not favour a concentration of fire on one point, it is preferable to form the battery of several faces. Should the faces be long, provision against enfilade should be made by erecting traverses, or even casemates.

Several small batteries are better than a large one, but it is not advisable to give each fewer than 3 guns: they seldom have more than 12 each.

Although a grazing fire is the most advantageous against shipping, yet a battery constructed near the level of the sea (à fleur d'eau) would be commanded. A height of 50 feet is the best. Above that the dead angle in front of the battery would be too great, and the fire too plunging.

When the coast is very steep, the battery is erected on the culminating point, because, if it were mid-way up, the projectiles of the enemy, although missing the work, would be arrested by the side of the hill, and thereby cause injury to the defenders: should the crest of the coast be too far off, the battery is constructed at the foot, near the level of the sea, and is protected by making the parapet as high as possible, and cutting embrasures for the guns.

The parapets, having to resist the heavy calibres of the navy, are made 21 feet thick, and the guns firing en barbette on traversing platforms, are placed 30 feet apart.

As long as the battery forms part of a fortress, it consists of the mere epaulment, but when it is isolated it should be made secure against a coup-de-main. In that case, it is surrounded by a ditch, flanked by a caponier, or by a loopholed wall, and by a glacis. A reduit for the garrison, serving at the same time as barracks, magazines, &c., is necessary, and its best situation is at the gorge of the battery, at about 30 yards from the guns, so that the splinters of masonry may

not injure the gunners. The redult should be covered from view by the parapet: it has a platform with machicoulis, &c.

Should the space be too narrow to construct a battery, as it will happen on cliffs, or islets near harbours, where the wash of the sea would endanger earthworks, forts or towers of masonry are constructed: they consist of several casemated tiers of guns. Sometimes such forts are erected on artificial foundations of concrete. These are expensive, and liable to suffer much, but it is sometimes impossible to defend the approaches of a port in any other way.

(352). The armament of the batteries will soon be altered by the introduction of Armstrong guns, but it is still regulated on the principles proposed in 1852 by a royal committee. At Portsmouth, however, a few 100-pounders Armstrong will be in battery before these pages leave the press.

The 8-inch shell gun, and 32-pounder of 56 cwt., are the best ordnance for general purposes, since they are capable of setting ships on fire. It is advisable to have one-third of the guns of the first kind, and two-thirds of the second. For important points, great roadsteads, &c., 10-inch shell guns and 68-pounders are recommended. For a shallow beach, the 32-pounder of 50 cwt. For short ranges, light guns and howitzers will be sufficient, whilst the 18-pounders are desirable for the batteries of position connecting forts with one another or with batteries.

Mortars are too uncertain against shipping to be much used, but for some particular cases, it is desirable to have a few 13 or 10-inch at hand.

The batteries should be provided with ammunition to last one day's firing, which is secured in powder magazines situated either in the redult or under the parapet itself.

The ammunition is calculated at the rate of 150 rounds for solid shot guns, and 120 for shell guns, besides a reserve of 100 rounds per gun kept in readiness. The proportion of shot and shells is:—for the former, 90 round shots, 20 shells, 20 shrapnells, 10 case, and 10 grape; for the latter, 80 shells, 20 shrapnells, 10 grape, and 10 case; but when it is for a 10-inch gun, the proportion is 100 shells, 10 grape, and 10 case.

It is also recommended to have hot shot furnaces placed to leeward in all batteries.

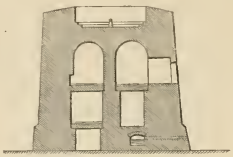
The guns are mounted on ordinary garrison carriages, and on all kinds of naval carriages. When firing en barbette, the traversing platform rests on racers raised on dwarf walls; when firing through embrasures or casemates, the racers are on the terreplein, and are traced on arcs, the centres of which are a little in rear of their muzzles.

(353). Every one is familiar with the *Martello towers* erected, in great numbers, on the southern and western shores of England. They were adopted in 1796,

and named from a small tower of Corsica, which had succeeded in silencing two men of war. They are of different sizes, carry one, two, three or more guns, and serve either as isolated batteries, or as reduits to unrevetted works, or even as forts.

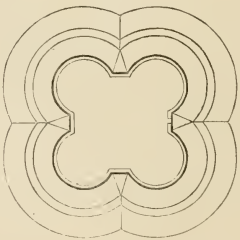
The small Martello is circular, with a diameter of about 30 feet, and a height

Fig. 660.



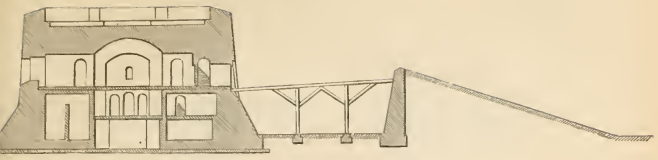
of at least 24 feet, to resist escalade. The platform is surrounded by a parapet of bricks, and mounts one gun, traversing on a central pivot. The upper story is bombproof, to serve as a lodgment to the garrison, and is pierced with loopholes, fire place, &c. The lower story contains the magazine, cistern, &c. The door, 10 or 12 feet above ground, is reached by means of a ladder: the platform and lower story, by means of a trapdoor and steps. The thickness of the walls varies from 6 to 12 feet. The large Martellos are not circular, but of a tracing that

Fig. 661.



varies with the number of guns they mount. The diagram represents a tower for four guns.

Fig. 662.



(354). The *tours-modèles*, which were recommended by Napoleon as reduits for coast batteries, are similar to the Martellos, and also vary in size, there being six types adopted. We represent tower, No. 1. It is square, measures 36 feet

Fig. 663.

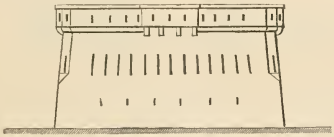
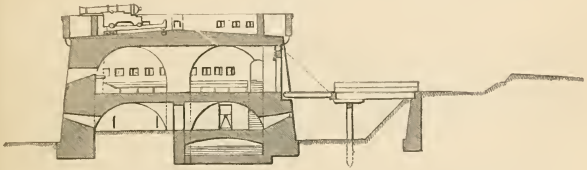


Fig. 664.



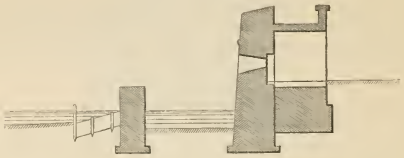
inside, and is 27 feet high, with a command of 18 feet over the surrounding ground. The platform carries four guns: it has a parapet of masonry loopholed, and provided with machicoulis for the defence of the foot of the tower. The upper story, which is bombproof and loopholed, contains the garrison, and is armed with two guns for the defence of the door. The lower story contains the magazine, cisterns, &c.

The advantage of these two descriptions of towers is that they are secure from escalade by a landing party, but they have very serious defects. They are expensive, the thickness of masonry being necessarily great, on account of the

vaults resting on the escarp itself, and yet this mode of construction facilitates the breaching. The artillery and gunners are much exposed, both to the enemy's fire and to splinters, and 3 feet of earth should be laid over the vaults to make them really bombproof. Round towers have this advantage over others, that they require a less amount of masonry for the same interior space.

A better disposition for the walls of batteries facing the sea is to be found in the block-house of Portsmouth.

Fig 665.



(355). The Russian works which in 1854 defended the bay of Bomarsund, consisted of a large fort and three round towers. The fort had the form of a semi-ellipse, the great axis of which measured 1000 feet, the small one 640 feet. It consisted

Fig. 666.

of two stories of casemates for artillery. The gorge was closed by two buildings serving as barracks, and by a strong work of the form of a horse-shoe also casemated, and designed to defend the approach by land. The fort could mount 100 guns, and provide accommodation for 2500 men, besides room for magazines. It was however found that at a distance of 1000 to 1500 yards, 6 guns only could be brought to bear at the same time on a ship. The towers, 140 feet in diameter, also casemated in two stories, were pierced with embrasures for 32 guns, each embrasure being flanked by two loopholes. Six feet of sand covered the top of the arches, and over them was a roof of timber and sheet-iron, intended to keep off

Fig 667.

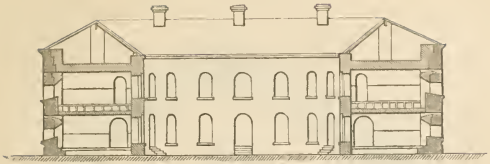
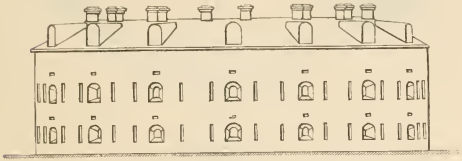


Fig. 668.



the snow. A British battery of three 32-pounders of 42 cwt., made a practical breach at 900 yards in about 8 hours. It is true that the construction of the masonry was bad: the front and rear walls had no tie with the piers and arches; and the front walls themselves were made of two unconnected parts, a coating of granitic blocks and a back part of ashlar.

The attack of Bomarsund, besides showing the difficulty of concentrating fire from circular casemated works, pointed out the danger of embrasures of masonry: most of the guns had been disabled by the deflection of the shots striking on the cheeks, and the Russians could not fire at long range because the openings of the embrasures were not sufficiently large to allow the guns to be elevated.

(356). Several batteries are now in course of construction in England, and to give an idea of the principles which engineers especially pay attention to at present, we exhibit the plan of a battery lately erected at the entrance of Shoreham harbour. It stands 50 feet above the level of the sea, in an excellent position for viewing the approaches, and mounts six heavy guns.

Fig. 669.

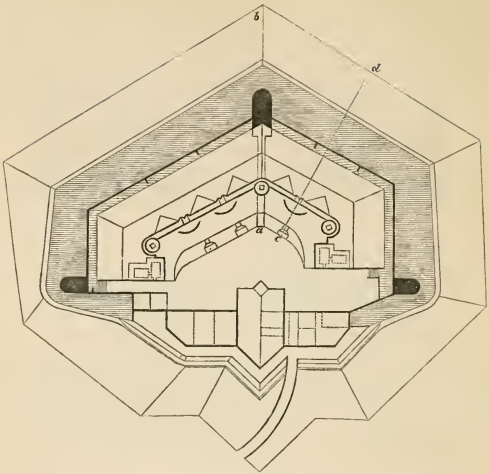


Fig. 670.

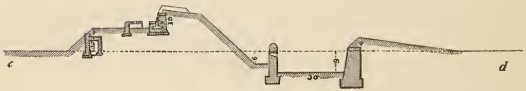
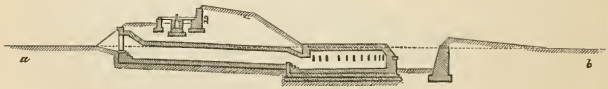


Fig. 671.



The guns fire en barbette and through wide embrasures, which permit them to traverse over a large field: the powder magazines are well secured under the extremities of the parapet; and shell recesses are built under the rampart. The

ditch is defended by three caponiers and by a Carnot wall, behind which is a chemin des rondes, and to this access is given from the terreplein by flights of steps. The gorge is closed by fire-proof buildings, serving both as barrack accommodation and as keep: they are preceded by a covered way and glacis, and are protected by the rampart of the battery. The few loopholes pierced through the gorge cannot prevent an enterprising enemy from reaching and then escalading it easily; in that respect it is scarcely secure against surprise: the Carnot wall is here employed to prevent such an occurrence along the faces, but if a caponier had been erected at each shoulder-angle, and the central caponier placed at the gorge with a ditch as deep as those of the faces, which is not the case at Shorcham, the danger of a surprise or of an attack de vive force would have been lessened, and the latter rendered impossible if the caponiers instead of musketry, had been organized for light howitzers firing grape shot.

CHAPTER XXII.

DETAILS OF PERMANENT WORKS.

SECTION I.—Defilade.

(357). The defilade of permanent works is based on the same principles and executed in the same manner as that of field works, but very few fortresses are found in which the problem is satisfactorily solved. The engineers of the time of Vauban did not attach sufficient importance to this subject. Cormontaingne was the first to take it in hand, and it has been necessary for modern engineers to correct, as best they could, the defects of existing fortresses; dangerous heights have been lowered, parapets raised, or terrepleins lowered, or these three means employed simultaneously.

The theory of defilade originated with the French school of engineers of Mezières towards 1760. At first the engineers imagined, for the sake of regularity, a single plane of site tangent to the commanding ground, and constructed their fortification on it as on horizontal ground. As the enemy does not make his approaches on this plane of site, but on the ground itself, this method could not answer practical purposes. A single plane of site for a place is no longer considered a necessity, far from it; every front or part of a front may have a special plane, and the more numerous these planes are, the more readily the fortification will bend itself to the ground, and thereby acquire additional strength. The distance from which it is advisable to defilade, is still a matter of discussion, but as 1000 yards is the extreme distance at which the besieger constructs his batteries, most engineers would defilade the enceinte from all commanding ground within it; this however is not sufficient when the place is exposed to reverse fire, because the enemy, with the actual improvement of artillery, may find it advantageous to erect batteries at a distance of 1500 or even 2000 yards, to fire at reverse on the defenders of the fronts attacked.

Ravelins or similar outworks are defiladed from 1000 yards only, because the enemy is not likely to erect special batteries on the rear of the parallel, and as the

covered way is not in request until after the besieger has constructed his second parallel, it requires defilading only from 600 yards. The masonry does not require defilading beyond 1000 yards. In general, this is the distance from which it is necessary to be covered from musketry fire; arms have been improved, but sight remains the same.

The plane of defilade should pass 8 feet above the dangerous ground, within musketry range, and 6 feet above the ground on which the enemy can erect his batteries. If possible, the salient places of arms should be defiladed from the spot on which trench cavaliers are constructed, the plane passing 9 feet above it. Every work should also be defiladed from those in front, the enemy being supposed to stand 3 feet above their parapets.

Defilading by sinking the terreplein is more frequently employed in permanent than in field fortification, although both methods are used. In general, we admit no plane of defilade with a greater slope than $\frac{1}{10}$. When the faces of a work cannot mutually cover each other without too great a relief, traverses are constructed to intercept the reverse fire, and cover the men on the banquettes, but they present serious inconveniences in outworks, where they mask the fire of the enceinte, afford more or less shelter to the enemy, hinder the communications or narrow the terreplein.

In field fortification, where the relief varies within narrow limits, it is often possible to defilade a work by modifying the outline, and although in permanent fortification the limits of the relief are wider, yet the conditions of the tracing are less easy to depart from. Nevertheless it is often necessary to make alterations in the general outline. The application of fortification to irregular ground is by no means the least important branch of the science, and we cannot do better than enumerate briefly the fundamental principles.

When a fortification is erected, either in horizontal or uneven ground, in front of an isolated height, its general direction should be perpendicular to the line that joins the commanding point to the extremity of the work, in order to obtain a plane of defilade as little inclined as possible. If it is constructed before a range of hills or equal altitudes, it should be parallel to those heights. If the crests of those hills gradually incline and intersect the plain, the fortification may no longer remain parallel, but may converge towards the point of intersection. When the fortification is erected on the side of a hill, in face of a plain, it should remain parallel to the latter, and if it must descend towards it, it should do so as obliquely as possible, the summit being occupied by the salient, and the foot by the re-entering parts, since it is from the foot that the enemy can direct enfilade and slanting fire.

If the whole place is situated in a valley, the longest sides or fronts are kept parallel to the hills, and the extreme ones that run across the valley being exposed

to enfilade and reverse fire, are made as short as possible and defiladed by traverses and parados.

When a work has a height in front, it is so much the more easily defiladed as its angle is more open; under such circumstances the bastions should have as wide a salient angle as possible, and flanks as short as the necessity of the defence will permit: ravelins may be dispensed with or have very little saliency. Whenever the position of a salient is not necessarily determined by other circumstances, it is fixed so as to let the prolongations of the faces fall on low parts and contain between their angle the dangerous ground.

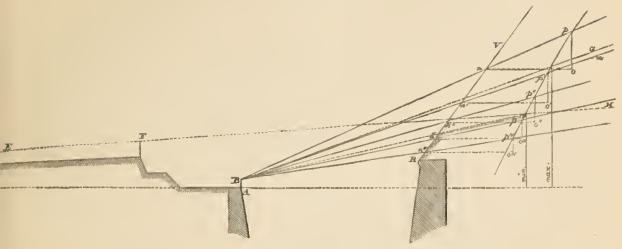
As a general rule, we should avoid the vicinity of commanding heights, and be especially careful not to direct long faces towards them. More particularly still, should we leave aside positions surrounded by hills within range. And lastly, it should be borne in mind that a fortification constructed on a slope facing a plain, stands in the same danger as a work erected on a plain and having a hill in front, that the most advantageous position for a work in uneven ground is on a surface rising towards the heights, and the most disadvantageous on a surface sinking towards them. Besides these considerations relating to the defilade, which apply to field as well as to permanent works, there are others that concern the ground itself on which the fortification is erected. Thus, an irregular surface requiring great deblais and remblais should be avoided; the salients, bastions, and cavaliers should be placed on the chief elevations, the ditches should occupy the hollows, the glacis should as much as possible coincide with the ground itself, &c.

(358). Fortifications are sometimes erected in mountainous districts to command a road through which the enemy is obliged to pass, and in this case the general principles cannot be adhered to. Space will frequently be wanting, fronts will be made smaller; and as the depth of the ditches must still be sufficient to prevent escalade, casemates, loopholed galleries, &c., may be employed. Sometimes earthen parapets will have need to be entirely replaced by masonry, blindages, vaults, &c, to protect the defenders from plunging fire. The fortification becomes similar to that of the ancients. It would be endless to enter into the details of the various cases that may occur in mountainous regions, but as a general rule we may say, that the chief work, fortress or fort, should not be erected on the culminating point, because the enemy might turn it by the paths he finds on the flanks of the mountains. This point is occupied by a tower, a blockhouse, &c , and the chief work stands in the valley towards which all the paths that lead across the chain converge.

(359). Although it is not our province to enter into details of plan-drawing, yet we may show how the command of works may be determined, by means of profiles, from the conditions that may be given. Let us suppose that it is required to find the command of the bastion over the glacis; the parapet being intended to

fire at the foot of the glacis, the shot to pass 4 feet above the crest, and to enable the defender to see 2 feet above the counterscarp.

Fig. 672.



Let E H represent the line passing through the foot of the glacis, and a point F, situated 4 feet above the crest of the covered way. Take A B = 2 feet, and through B draw a line B G, inclined at $\frac{1}{6}$. It is clear that the crest of the parapet must be between the lines F H and B G: if on B G, it will give the maximum command compatible with the data of the problem; if on F H, the minimum.

Through R draw R V at 45° to represent the direction of the exterior slope, and through B draw several lines B *m*, B *m'*, B *m''*, &c., which may represent various superior slopes: from the points where these lines cut R V, measure horizontally *n o* = *n' o'* = *n'' o''* &c. = 18 feet thickness of parapet, and erect the perpendiculars *o p*, *o' p'*, *o'' p''*, &c. The points *p*, *p'*, *p''*, being joined, we obtain a curve (hyperbola) on which the crest must be situated, since R *n*, R *n'*, &c., represent the exterior slopes, and *n o*, *n' o'*, &c., the superior ones. The intersection of this curve with B G and F H will give the command maximum and minimum.

SECTION II.—Communications.

(360). Great importance is now attached to the establishment of good communications between the various parts of a front, because the defence may receive a greater impulse when there is free circulation, than when there is danger of being cut off or exposed to view while repairing to the threatened point. The chief conditions they should fulfil were not always observed in old constructions, but now engineers endeavour to obtain them: they should not compromise the safety of the enceinte or of the works to which they lead; they should be easy of access to the defenders and yet useless to the enemy; and they should be covered

from the sight of the besieger throughout the whole of the siege; their egress (when underground) or their surface should be seen from the works in rear, in short, they should not be easy to be cut off by the enemy.

These communications take place, as we have seen, by posterns, stairs, ramps, and caponiers.

(361). *Posterns* are subterraneous passages and must only be constructed when indispensable, because they more or less facilitate surprise. If in pursuing the defenders actively the enemy succeeds in entering such passages and occupying them even partially, he is enabled to barricade them; to fill them with powder and blow up the work above: it is a danger to which all subterraneous passages are subject, hence canals, rivers, sewers, aqueducts, &c., are invariably closed at

FIG. 673.

their ingress and egress by gates, and otherwise made secure. Posterns are generally found under the middle of the curtain, under the tenaille, under the flanks of the redoubt of the ravelin, under each face of the redoubt in the re-entering places of arms, and sometimes under the faces of the cavalier in lieu of the staircases which we have seen round the traverse in the modern system. As a rule, they should not be inclined at a greater slope than $\frac{1}{6}$, and this is why it is so often necessary to make the great postern under the curtain debouch about 6 feet above the bottom of the ditch, a disposition, however, which prevents the enemy from forcing the entrance by attaching a petard. A wooden ramp completes the access in ordinary circumstances, but when there is danger in letting it remain, it is replaced by a moveable light wooden staircase. It has been proposed to let the postern reach the bottom of the ditch whenever the slope allows of it, and to defend its approach by a loopholed guardhouse, but it increases the expense and is not always practicable.

The postern through which artillery passes should be 7 feet wide by 9 feet high, except the great postern, which is usually 12 feet by 9; those destined for infantry are 5 wide by 7 feet high. In ancient fortifications, the posterns under the curtain, cavalier, and tenaille, were the only ones through which guns could pass, but most modern engineers require that all posterns be made wide enough for artillery, to *save time* in arming and disarming the outworks, an operation somewhat slow, since the guns and their carriages have to be carried from the main ditch to the various terrepleins by means of gyns.

Both entrances of a postern are closed by strong gates opening inside, and a third gate "of safety" is frequently erected in the middle of the passage. These gates are made of oak strengthened by iron, and are besides secured by oaken balks inserted into the masonry of the vault.

The posterns of the enceinte are frequently turned to advantage: recesses are cut on both sides of the passage to form powder magazines, which besides being bomb-proof are very handy for the outworks.

In the modern system the posterns which lead to the ditch of the ravelin open into the terreplein of the redoubt, but French engineers object to this arrangement: they believe that every work should have its own special communication, and they make these posterns pass under the flanks of the redoubt and open into the main ditch.

(362). *Stairs* or *pas-de-souris*, were exclusively employed in the time of Vauban, to communicate from the ditch with all the outworks: now they are

FIG. 674.

found, either single or double, at the gorges of the salient places of arms, of the redoubts in the re-entering places of arms, of the redoubt of the ravelin, of coupures, and of tenaille.

They are a precarious means of communication, for the vertical fire of the enemy destroys their steps, or the frost makes them slippery, and even when not so impaired, they are by no means easy to ascend rapidly. Vauban made them only 3 feet wide, and their slope was nearly 45°. Cormontaingne widened them, and diminished the slope: at present they are 6 or 7 feet wide; the step is 7 inches high, and the thread 11 inches, giving a slope of $\frac{7}{11}$. A thread of 14 inches gives a better slope.

These stairs are greatly objected to by many engineers who prefer ramps fit for artillery, except at the gorge of the redoubt of a ravelin, which a ramp might expose to be turned.

(363). *Ramps* are undoubtedly a more rapid means of communication, but it is yet a matter open to discussion whether *pas de souris* are not preferable. The outworks once armed, their artillery need not be moved till it is disabled: and if any can be saved, it will not be of great importance to the defence, whilst ramps offer easy access to the enemy. Besides those usually constructed for the re-

entering places of arms, the ravelin and the coupure in the bastion, many are erected for the barbettes of bastion, ravelin, redoubt of ravelin, and for communicating from the terreplein of enceinte with the rampart, and hence with the cavalier. Their width varies from 9 to 15 feet, and their slope from $\frac{1}{6}$ to $\frac{1}{12}$, or more, their inclination diminishing as the difference of level increases. Whenever ramps or stairs are exposed to the view of the enemy, it is necessary to cover them by special masses of earth, or traverses, which protect the defenders.

(364). *Caponiers* serving as communication, although organized defensively, are mere traverses; their glacis should always be exposed to the fire of the parapets. The double caponier in front of the tenaille can be plunged by the enemy when he is established on the glacis of the bastion, and this is why it is often recommended to replace it by a vaulted passage.

(365). *Sally-ports* have no other condition to fulfil than that of avoiding enfilade; one is cut through every face of the re-entering place of arms, and another through every branch of the covered way of the ravelin near the salient place of arms.

(366). Besides these communications which are indispensable for every front, a place requires *gateways* to communicate with the country, for the use of the inhabitants in time of peace, but these are dangerous for the security of the place, and their number should be limited to what are strictly necessary.

Although there are small places having only one gateway, two are deemed necessary, in ordinary cases, for fortresses of four, five, six, and even seven fronts; in general one gate for every three or four fronts is the average, unless the place be divided into segments by a river, when two gates per segment are indispensable. As much as possible they are constructed on the fronts which are least exposed to attack, and always in the curtain: it is through them that great sorties with all arms are made, and it is important that they should be safe.

The gateway is a vaulted passage, debouching from the scarp 3 or 4 yards above the bottom of the ditch, and closed by a drawbridge and by a gate of safety in rear. A loopholed guard house, between that gate and the drawbridge, defends the passage. Hitherto, when there was no outwork, the entrance was further defended by means of herses and orgues. Herses were strong wooden barriers, which were raised or lowered by special machinery, through a vertical slide cut into the vault; but as they could not be lowered when the enemy had succeeded in bringing a cart under them, orgues were substituted. These are strong balks of wood sliding through grooves, and exactly closing the passage.

(367). The drawbridge leads to the tenaille, through the parapet of which an opening is cut: there another drawbridge (often dispensed with) communicates with a fixed bridge that leads to the redoubt of the ravelin. At that point the

Fig. 675.

road turns nearly at right angles, and passes through the faces of the redoubt and of the ravelin under vaulted archways provided with drawbridges over their respective ditches, thus forming a level communication with the covered way, from which a winding cut, opened through the glacis, leads to the country.

For further security a small place of arms, called "avancée" is constructed at the point where the road leaves the covered way.

There would be great danger in tracing the road in a straight line, because then the enemy might enfilade it, and render great sorties impossible.

The entrance to the curtain is generally decorated with some architectural structure of simple character.

The passage is 15 feet wide, the gate from 10 to 12 feet, and the vault 15 feet high, dimensions greater than those we find in ancient places. They allow for two paths for foot passengers. In commercial towns, however, two passages, one for egress and another for ingress, are often coupled together. The height of the vault, with a thickness of two yards for its masonry, and the earth above, does not always suit the relief of the curtain, and it becomes necessary to raise the curtain in the middle, or to erect traverses or cavaliers at that point. Where these means are not sufficient, the passage is not vaulted.

The fixed bridges over the ditches are solid structures of wood or masonry, or the piers are made of masonry and the rest of timber, in order that it may be easily cut or destroyed. The bridges are from 18 to 30 feet wide according to their importance.

As they, more or less, hinder the flanking of the ditch, the arches are made as wide as possible, and when the passage is not much above the bottom of the ditch, a causeway is carried from the tenaille to the redoubt of the ravelin with two glacis well defended by the flanks: a coupure of 12 or 15 feet is made near the counterscarp.

(368). In order to interrupt or re-establish suddenly the communication, drawbridges are employed, which consist of two parts, the platform and its counterpoise.

The platform, about 12 or 14 feet long, is a stout frame of timber, the head and tail piece of which are connected by balks. Over these one or two rows of chesses are placed, and to prevent the wheels of carriages from wearing away their surface too rapidly, small iron bars are closely set over them on both sides. The tail piece bears two iron pins driven right and left into the scarp wall, which wall is made thicker under this part, to prevent accidents, and above it a recess is cut to receive the platform when the communication is interrupted. The head is secured to the fixed bridge by two bolts, and hand-rails are placed on both sides.

This structure has a great weight, and requires a counterpoise in order to move it, besides other means designed to surmount inertia and friction; hence the invention of several systems, but we shall only say a word on the chief ones.

In the most ancient, the counterpoise is formed by a stout wooden frame, heavier than the platform, terminated by two long beams called "fleches," which

Fig. 676.

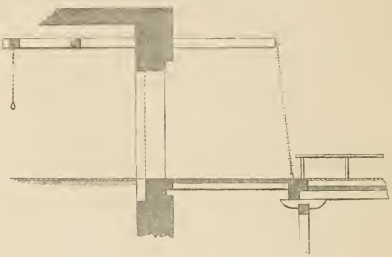
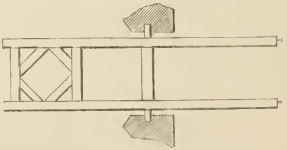


Fig. 677.



are strongly connected and protrude outside. They bear pivots fixed in the wall, whilst their extremities are secured to the head piece of the platform by a chain. The part of the counterpoise or bascule in rear of the pivots, must have sufficient weight to balance the platform. The length of the beams, from the pivot to their

head, is equal to that of the platform, and the distance between the pivots of the counterpoise and the pins of the tail piece must be equal to the length of the chain connecting the fleche to the head piece. To work this bridge, the bolts that secure it to the fixed bridge are opened, the bascule is pulled downwards by a service chain, and the fleches turning on their pivots raise the platform. Two vertical grooves are cut into the masonry to receive the fleches. The inconvenience of this system is the danger to which the long fleches, seen at a distance by the enemy, expose the bridge; the efforts made to raise the platform are not constant during the working; the equilibrium is soon destroyed by the warping of the beams, and the timber of the fleches requires frequent repairs.

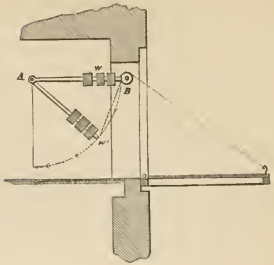
(369). To avoid the inconvenience of exposure to view, the bascule has been fixed below, and received into a well hole when the platform rises. This plan is

Fig. 678.

more common in Germany than in France. The scarp wall requires a great thickness; when the ditch becomes wet, the well-hole is liable to be filled with water, and the counterpoise acquiring buoyancy no longer balances the platform. Sometimes a system of cogwheels is employed to lower or raise this bascule.

(370). In a system due to Dobenheim, the effort necessary to work the bridge varies with the resistance which the mass presents in the different positions it may take. The platform is balanced on the right and left side by two iron bars, one horizontal, the other inclined at 45°, both carrying a weight at their extremity. Each bar is moveable separately round an axis A, whilst the weights are connected by a chain which passes over a pulley B, and is attached to the head piece. By pulling the weight W, the platform is raised, both weights acting simultaneously until an arc of 45° has been described, when w' falls on the vertical, and ceases to

Fig. 679.



act, w raising the platform. The mechanism is simple, but it does not exert a constant power.

(371). In the system of Belidor, the counterpoise formed of iron cylinders, roll on each side on a curve called sinusoid, which is proved in mechanics to possess the property of diminishing the weight of the counterpoise in the same proportion

Fig 680.

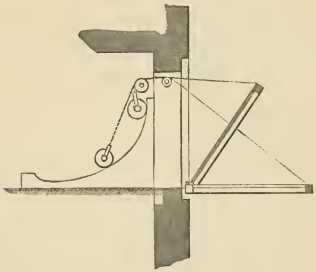
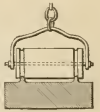


Fig. 681.

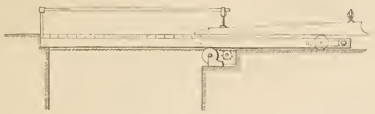


as the platform loses its own when being raised. The curves are made of masonry and bear a rail of iron, on which the cylinder rolls. In practice, the friction renders the working difficult, and this plan requires also much space in rear.

(372). In the roller bridge of M. Lesueur of Jersey, the platform and counterpoise belong to the same frame-work, made of oak beams strengthened with iron

rails. Under it is a rack, bolted to some iron bearers which connect the whole frame. The counterpoise rests on the edge of the escarp, on a roller, whilst at the

Fig. 682.



rear it is provided with a truck and friction-rollers. By means of a pinion and cogwheel, the platform, or rather the bridge, is moved inside the place; the handrails themselves following and passing on rollers mounted on standards. The working is not exposed to danger, but it is slow and requires much space in rear; and means must be provided to close the opening.

(373). The last sort which we shall notice, due to General Poncelet, is frequently employed in France, where engineers seem to attach as great an importance to constancy of the power, as to security of working.

Fig. 683.

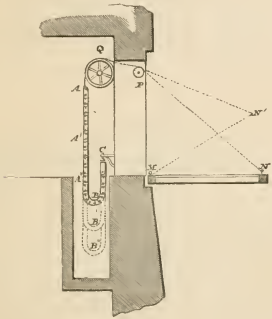
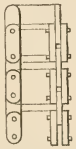


Fig. 684.



Here the counterpoise consists on each side of a massive iron chain, attached at one end to a fixed point *c*, and at the other to the small chain that draws the bridge. The great chain is made, as the diagram shows, on the same principle as that of a watch; it cannot touch the wall, because of the small chain rolling on a pulley, P passes afterwards over a wheel Q that keeps it off. The counterpoise set

into motion by one man, descends into a small well. When the platform is horizontal, the chain being on A B C, the part B C is supported by the fixed point C, and it is the weight A B that balances the bridge. When the platform is raised to M N′, a portion of the chain A A′ equal to the difference P N − P N′ descends, and the part that balances the bridge is A′ B′ alone, which is evidently smaller than A B, since B B′ is only half of A A′, in a third position a smaller part A″ B″ balances and so on, the counterpoise becoming smaller and smaller as the bridge loses more and more of its weight. The proper weight of the chain is fixed after a few trials, and as it is armed with hooks to receive additional weights, the matter is easily settled.

It is an excellent drawbridge, the working is easy and simple, it takes very little room, is not exposed, and has only the defect of being more expensive than those of the old system.

When railways pass across a place, it is not possible to give them the same curvature as the ordinary roads, hence a danger which it is necessary to diminish by the addition of advanced works. These works should be kept at the same level as the covered way, be traced perpendicularly to the front, and be seen along all its surface from the parapets. When railways pass under vaults, they should be defended by loopholed galleries.

During a siege, all the bridges are removed, the gates or openings through the escarps are closed by means of remblais, and the inhabitants communicate with the country through the posterns, those gates only being preserved on the fronts not attacked, through which sorties can be made in force.

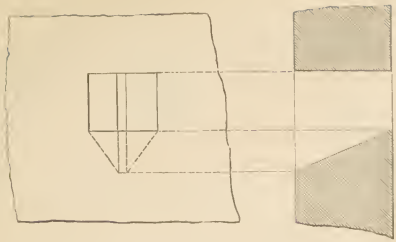
SECTION III.—Loopholes.

(374). Loopholes are of two kinds, horizontal and vertical, the former of which is rarely employed except for the defence of a ditch in the galleries of reverse and caponiers, where a wide horizontal range is required.

In vertical loopholes the exterior opening is 3 inches wide, and the interior opening 2 feet. The height must be such as to permit the men to fire easily in all the directions where fire is necessary, and varies from 1 foot 6 inches to 2 feet. The cheeks with these dimensions are inclined at 30°. The "plongée" varies with the requirements of the defence, and in mountainous districts it may even counterslope.

Fig. 685.

Fig. 686.



Sometimes the wide opening is made outside, and the cheeks are indented, thereby affording the same security as in the other arrangement: it presents a better view of the external object, and it may be adopted for caponiers and galleries of reverse, where the enemy has something else to do than to return fire.

When the wall is more than 3 feet thick, the muzzle of the musket cannot protrude outside, and the smoke would become inconvenient: in this case, a recess is cut in rear, or the loop may be made wider both ways. In this case, the exterior cheeks are indented to prevent the bullets of the enemy from ricocheting and passing through.

Fig. 687.

Fig. 688.

When a loop is pierced near the angle formed by two walls, it is necessary to allow 1 foot 6 inches between the wall and the cheek, otherwise the defender could not make use of the whole range.

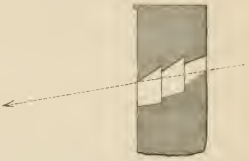
The exterior opening must be kept 7 or 8 feet above the ground outside to prevent the enemy from masking it or firing into it. When, however, the plongée needs to be much inclined to fulfil some condition of defence, the men cannot easily incline their muskets along its slope, hence the necessity of piercing the loophole down to the foot of the wall itself may occur. Such loopholes are called by the French "créneaux de pied." A plongée much inclined is usually indented like the cheeks.

The interior opening must permit the men to fire easily in every direction, and is therefore kept at 3 or 4 feet above the banquette. The centres of loopholes are usually kept 3 feet apart, not to weaken the wall too much.

The superior face (top) may be horizontal, but it is inclined when it becomes necessary to limit the vertical range, as in loops pierced through flanks that

Fig. 689

Fig. 690.



face each other, or as occurs in mountainous regions: this inclination prevents the men from firing at each other.

Loopholes are generally cut perpendicularly to the wall, unless they have to flank a face oblique to that in which they are pierced, or when several of them have to defend the same point.

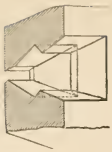
Fig. 691.

Loopholes may be double when it is necessary to fire in two directions, but they weaken the wall.

Horizontal loops are similarly constructed, and what has been said before applies to them; their opening may be wider outside or inside, their cheeks may be indented, &c.; the only difference is, that they may serve for two or even three men. Colonel Ord proposed this loophole for two men: it has on each face a break or return to arrest the bullets.

Fig. 692.

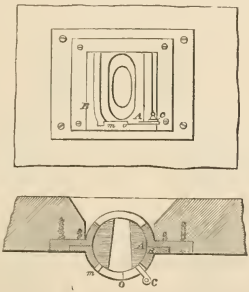
Fig. 693.



Loopholes cover the defenders from the musketry of the besiegers, but each man behind his narrow opening cannot see a large space in front, and is often unable to fire on the enemy when he presents himself only for a very short time before the range of his loop, especially when close. Loopholes should not be exposed to the view of artillery, hence they should be used sparingly, as auxiliary means to defend a bridge, or a ditch when the defence from the parapets is not efficient. In Algiers, where the Arabs have no artillery, the French have constructed places, the enceinte of which consists merely of a loopholed wall of the bastion trace.

In Germany, loopholes form an important item of the defence, and we shall have an opportunity of judging of their value when speaking of the polygonal fortification.

Fig. 694.



(375). A revolving loophole, that may be advantageously adapted to doors, and at the same time made to serve as a ventilator, has been lately tried at Chatham, and found to answer well. It consists of a solid cylinder of metal A,

that revolves in a casing B, also made of metal. The cylinder is pierced with a hole 2½ by 1½ inches, allowing an elevation of 14°, and a depression of 19½°. Apertures through the casing permit a horizontal field of 75½°. The cylinder is adjusted to the object to be fired at, by means of the barrel acting as lever. To close the opening, the cylinder is turned by means of a handle C, then raised over a cheek *o*, and kept closed by the handle fitting into the notch *m*.

(376). *Embrasures* for guns are loopholes on a larger scale. The question is not yet settled as to what is the best form to give them, and yet, owing to the multiplicity of casemated works, caponiers, coast batteries, &c., lately constructed, it requires a speedy solution. The two great points to bear in mind in the construction of embrasures are to cover the gunners, and to obtain a wide field. In the old model, the throat was 2 feet 2 inches wide, whilst the outside opening

Fig. 695.

was made equal to 2 feet 2 inches, increased by one third the thickness of the wall. The gun can only traverse 27 degrees, and the outside opening is considerable: projectiles striking the cheeks enter the battery, and the acute angles of the masonry at the throats are liable to be broken in.

There would be less danger for the gunners if the embrasure were reversed, but

Fig. 696.

the thickness of masonry near the external opening would be too small. This form has been modified in recent construction thus:—

Fig. 697.

Fig. 698.

but if some advantage is thus gained for lateral range, the external opening is increased. It was with a view to avoid acute angles at the throat that the

Americans adopted the embrasure of General Totten, in which the throat is at 2 feet from the face of the wall, the exterior opening 4 feet, the interior one 5 feet, and the external height of the cheeks 2 feet 6 inches, the throat itself

Fig. 699.

being 1 foot 10 inches wide. In the construction of coast batteries, American engineers have kept in view the great danger to which the gunners are exposed when ships can approach sufficiently near to use canister, the balls being "carried in" in large proportions; and to remedy this defect they have adopted an embrasure into which the projectiles can only enter through a small opening, the width of the throat itself. But in their new embrasure the masonry is weak at the throat, and

Fig. 700.

liable to be destroyed by heavy ordnance, so much so that they have to strengthen it by wrought iron slabs. Experiments are still going on, and it is thought that we shall soon possess embrasures coated with iron, really shot proof.

To prevent small shots entering the embrasure, iron mantlets or shutters are

Fig. 701.

Fig. 702.

advantageously employed: they are kept closed whilst the men are loading the gun.

(377). *Machicoulis.*—We have already spoken of the use of machicoulis (344), and we now give an application of loopholes and machicoulis, as proposed by General Dufour, for a tower of 24 feet radius, destined to be defended by a garrison of 40 or 50 men. This arrangement is advantageous in mountainous districts (358).

Fig. 703.

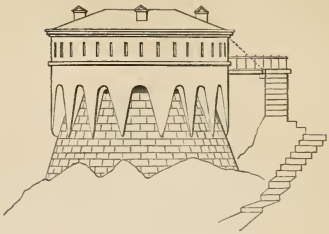
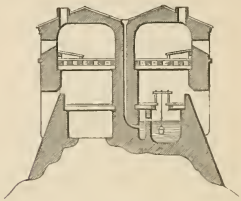


Fig. 704.



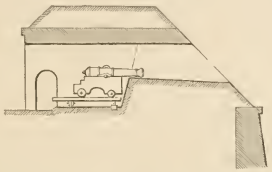
SECTION IV.—Casemates.

(378). Casemates, or vaults destined to protect troops against vertical fire, and constructed under the ramparts or elsewhere, form an excellent addition to all fortification; but opinion is divided on casemates for guns intended to perform an important part in the defence. They have found strong advocates since the discovery of ricochet and the employment of vertical fire, and it is argued in their behalf that both gunners and guns are safe against such fire, and that by placing casemate above casemate the defence may acquire a great superiority of fire over the attack. But if a casemate commands a view of the approaches, it is exposed to direct fire, the wall is easily breached, and the shot that enters through the embrasure causes much harm: besides, the smoke is always more or less troublesome. Whatever be the system of ventilation adopted, it will happen in still weather, as is often found in the ditches of a fortress, that the smoke will remain many minutes outside, before the mouth of the embrasure. The casemate

is almost in the dark, nothing can be seen, and the precision of fire cannot be relied upon. Therefore, of two batteries of equal force, one on the ground, the other casemated, the latter will be under a disadvantage. As for the superiority of fire, it is a doubtful question, for it would imply an immense expense to construct stories of casemates on every front exposed to attack, as well as an immense armament; and even then, the besieger, instead of superposing his guns in one battery, could extend them horizontally, thereby presenting a more uncertain aim, and often avoiding the range of the embrasures, whilst every one of his shots would tell on the stories of the casemates. The great armament of the defence will only necessitate more powerful battering trains than have been hitherto employed.

As accessory means, however, casemates are excellent. They should be 15 feet wide and 15 long when open on the rear, or 20 when closed: the height of the vaults should vary from 9 to 15 feet. The piers of the vaults are 3 feet thick, and are pierced with lateral openings to give room to the men and facilitate the circulation of air; and vents or chimneys should be so contrived as to permit the smoke to escape freely. The embrasures have the shape of loopholes, and

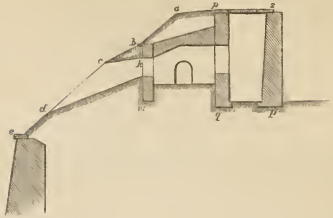
Fig. 705.



the genouillère should be made as high as possible to protect the men from any shots that may enter through the embrasure.

(379). General Haxo, a French officer, has proposed casemates that bear his name: they have been constructed at Grenoble and other fortresses. They consist of a vault thrown over the gun situated on the terreplein of a work, but not over its embrasure. It is open at the rear, and acts as a traverse. The cheeks of the embrasure are revetted with fascines. The fire is thus less plunging than from guns in barbettes, the smoke circulates freely, the masonry is not exposed, but the merlons do not present a great resistance. They are 12 feet wide by 18 long, and 9 feet high; and above the genouillère they are only 6 feet high. These dimensions are too small, and as the genouillère can only be 3 feet high at the utmost, the gunners are exposed.

Fig. 706.



If *e* represents the top of the escarp, *e c* the exterior slope, and *c h* part of the superior slope of the parapet, the casemate is contained by the wall *b m* buried in the parapet, and the wall *p q* which is pierced with a large hole for the passage of the smoke. A slope of earth *c b* covers the masonry. On the roof of the casemate stands the new parapet *b a p*, which may serve for a second tier of guns. Wells *p q r s* pierced through the terreplein connect the several casemates of a battery, and give issue to the smoke.

The advantages possessed by these casemates are great: they take up but little space on the terreplein, which remains sufficiently large or requires but little remblai to afford room for a second tier; their embrasures may be marked by sods, so that they may be concealed till the moment they are called into play, and the garrison finds bombproof covers. The earthen embrasures do not, however, allow so wide a range as those of ordinary casemates.

The wall in the front is still liable to be destroyed by direct fire, and this defect it is attempted to remedy by coating the exposed part with iron. Until these attempts prove successful, it is prudent to construct these casemates on the parts of the rampart which are not likely to be exposed to direct fire. The vault lowering towards the front impedes the gunners; to avoid this, in recent constructions, it has been made of uniform height. The rear wall is also suppressed. The annexed figure represents a casemate for two guns as executed at Gosport.

Fig. 707.

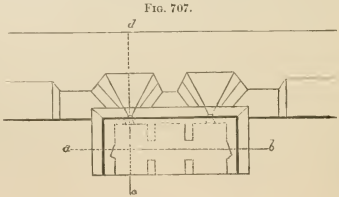


Fig. 708.

Fig. 709.

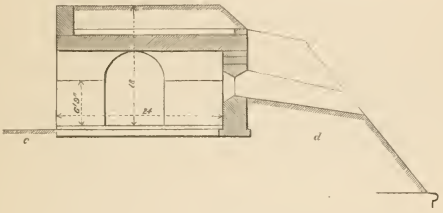


Fig. 710.

(379 a). *Powder magazines* are found in every fortress. Those containing enough of made-up ammunition to last 24 hours, or *expense magazines*, are temporary bomb-proof constructions situated in the works themselves; there is usually one per bastion. The large or *principal magazines* are erected as far as possible from the fronts exposed to attack. These are strong buildings of variable form. The magazin of Vauban, containing 100,000 pounds of powder in tiers of three barrels, is an arched building 60 feet long, 25 feet wide, and 18 feet high inside.

Fig. 711.

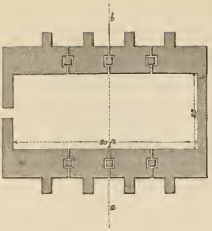


Fig. 712

The side walls are 8 feet thick, are strengthened by counterforts, the end walls are 4 feet thick, and the minimum thickness of the arch 3 feet. To prevent the powder from getting damp, some air holes are pierced through the walls so as to cause ventilation, and their peculiar form prevents anything being introduced through the opening, which is furthermore covered inside with a copper net, iron being entirely proscribed. Sometimes the building is formed of three or more arches. The following diagram represents a powder magazine at Lille, containing

Fig. 713.

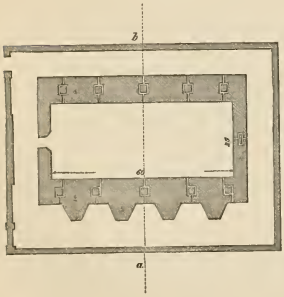
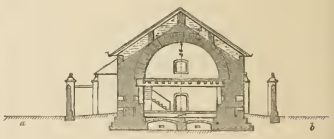


Fig. 714.



150,000 lbs. of powder. It is surrounded by a wall which masks the entrance. The counterforts of Vauban are objected to on account of their shadow, which causes the wall to keep moisture in the corners, and the form of these buttresses is an improvement, although many engineers would prefer to see the counterforts

constructed inside the walls. The arch is protected by 3 feet of earth, and the roof is made of sheets of lead. As there must always be much lead kept in store in fortresses for the casting of bullets, the metal may as well be kept in sheets, and thus serve for roofing, thereby saving the cost of repairs entailed by ordinary roofs.

SECTION V.—Water.

(380). The presence of water, despite its inconvenience in some respects, is nevertheless advantageous to the defence, and often renders it possible to simplify the fortification. When, for instance, water is found 2 or 3 feet below the surface of the ground, it is hardly possible for the enemy to construct his approaches, and the fronts, no longer liable to attack, may consist of an unrevetted enceinte with a long curtain and small bastions, a wide wet ditch with at least 6 feet of water, and a covered way.

If water is found at a greater depth, at 6 or 10 feet, the principles of Cœhorn (296) may be applied. The enceinte consists of a small front; the escarps are revetted, and 18 or 20 feet high, the ditch is 20 yards wide, and its bottom is kept just above the level of the water, so that the enemy cannot sap through it. Before it, stands a second enceinte formed of unrevetted counterguards and a tenaille similar to those of Vauban, preceded by a wet ditch about 40 yards wide. The ravelin is similarly organised, having a revetted scarp, a dry ditch, an unrevetted counterguard, and a wide wet ditch. A low covered way surrounds the whole, but its re-entering angles are not sufficiently deep to receive redoubts. But when water is 12 or 15 feet below the ground, the principles of the tracing need not be modified, the relief alone alters and becomes less, since the flanks need only preserve a view of the surface of the water. The ditch 18 or 21 feet deep, has an escarp raised 18 feet above water. Although it is preferable that the masonry should be carried to the bottom of the ditch, yet reasons of economy sometimes require this 18 feet scarp to be erected on a berm 6 or 9 feet wide left on a level with the surface of the water, but this can only be done in good silicious or calcareous soil. The tenaille needs no revetment except on the wings. The outworks are constructed either with dry or wet ditches. If their ditch is dry, the construction requires no alteration, but if it is wet, the ravelin may be left altogether unrevetted and its ditch widened. The redoubt is still revetted with its dry ditch, but is necessarily smaller on account of the space occupied by the earthern slopes of the ravelin. At last the glacis, on account of the reduction of command, must not be more than 6 feet above ground, because it would otherwise necessitate great remblais to throw up its glacis.

The communications across wet ditches may be carried by means of light bridges

as already explained (152), or by boats. In some French places however, they are organised as follows. The great postern opens on a level with the water, and a boat placed lengthways leads to the tenaille. To this work is attached a double caponier, the glacis of which are replaced by parapets; it extends to within ten yards of the gorge of the redoubt of the ravelin, and is at this extremity capped with two oblique traverses that limit the passage inside to 3 yards. The obliquity of these traverses enables the enceinte to flank the coupure of 10 yards that separate the caponier from the redoubt. Occasionally this caponier is replaced by a canal with defensive banquettes. A small bridge or a boat leads from the caponier to the redoubt of ravelin.

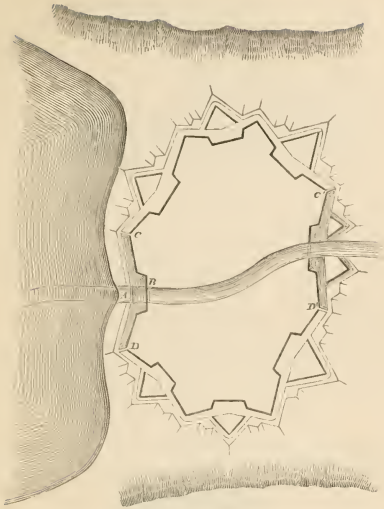
When the ditch of the redoubt is dry, the usual posterns and ramps are employed, but when it is wet, a berm 9 feet wide, follows at a level with the water the profile of the redoubt, and the gorge of the ravelin, where a coupure of 8 yards is again crossed by means of a boat, and is produced as far as the gorge of the redoubt of re-entering place of arms. The three coupures between the curtain and tenaille, between caponier and redoubt, and along the gorge of the ravelin, are deemed sufficient for security, but this system can scarcely be called an improvement on the old method.

(382). *Inundations* secure against attack the fronts they surround, and permit a more vigorous defence to be made on the others; they protect the neighbouring bastions from enfilade, and when they extend both above and below the place they hinder the investment, interrupt the communications of the enemy, and oblige him to construct bridges. When they are extensive, some lunette or redoubt erected some 60 or 80 yards from the shore, will often render the advance of the enemy impossible, or if the salients of the trace are protected by them, the enemy is compelled to attack the long intermediary sides as at Strasbourg. Their expense is not great when compared with the advantages they insure to the defence, and their only disadvantage is the unhealthy condition in which the garrison is placed by pools of stagnant water.

In marshy and low countries, natural inundations are sometimes produced by lakes and ponds, but the depth is rarely sufficient to afford security. The most favorable condition is when a river traverses a place erected in a valley, the sides of which have only a small inclination, more especially when the fall of the bed is not great.

The dispositions most generally adopted are as follows:—The course of the stream is intercepted at its entrance into the place by a sluiced dam or barrage, or what is better, by two of them in case the enemy should destroy one. The first constructed on the counterscarp A, is called sluice of "retenue" or of "prise d'eau," the second made under the rampart, or further in, if necessary, is called sluice of "sureté." By closing sluice A, the water rises on the bed, overflows and forms

Fig. 715.



an inundation above the place. This inundation is maintained at a proper depth by dams defended by advanced lunettes. If when the sluice A is open, B were also opened, water would enter the ditches, but it is not permanently allowed, because the mud deposited, would in time, raise the bottom. Batardeaux D, C, above, and D', C', below, prevent the water from entering. Inundations below the place are also advantageous, although they are more exposed to destruction by the enemy; they are maintained by dams across the valley, and fed by the inundation above, either through aqueducts or waste-weirs.

Auxiliary dams may besides be thrown up, both above and below, to cover a greater surface of ground, but they require works for their protection.

In some cases the inundation above the place may serve to flood the valley below on a sudden, by merely opening the sluices of "retenue" and of "sureté."

Besides the protection due to these inundations, the dispositions of which vary with every place, water provides active means of defence for the ditches.

The batardeaux D and C, are provided with sluices called flood gates, and those D', C', with sluices named sluices of "fuite," which permit the garrison to fill and empty the ditches at will. When a place is threatened with a siege, an inundation is effected, and the ditches are kept full till the latter part of the investment; but when the enemy has begun his approaches the water is let off to facilitate the communications and the sorties. When the besieger has fairly advanced, his passage across the ditch, the flood gates are opened and his work is destroyed by the impetus, and weight of the water; the sluices of fuite may then be employed to empty the ditch for the purpose of repeating the manœuvre called "chasse" by the French; or the ditch is kept full. The besieger having made a fresh descent and constructed a bridge across the ditch, the water is let off through the sluice of fuite, and through the flood gates too, when an impetus is required, and the ditch is again cleared. By these or similar measures the defence may be protracted.

When the volume of water is not considerable, intermediary sluices forming a sort of locks in the ditches may be constructed, so as to give chasses without draining the inundation.

(383). The barrage, as we said, is made either under the arches of a bridge in the town or under the rampart. The most simple consists of sliding beams which are let down one by one into vertical grooves cut into the piers; two pairs of grooves in front and two in rear of the arch are usually cut, and the interval

Fig. 716.

between the two barrages may be filled with earth. Every beam has a ring near each of its ends, so that by means of a hook, it may be removed or let down to keep the water at the requisite level.

Sometimes the grooves receive a gate which is raised by a crab or by winches, but the pressure of the water renders the working difficult.

Another sort of barrage is made with vertical beams; a strong wooden structure, a bridge for instance, is run across the bed or between the arches of a stone bridge. The beams are thrust into the river one by one at an angle, as shown in the diagram, the stream acting on them brings them to the vertical, and their lower extremities rest on a sill made either of wood or of masonry.

Fig. 717.

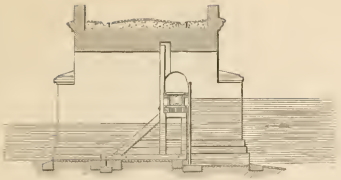
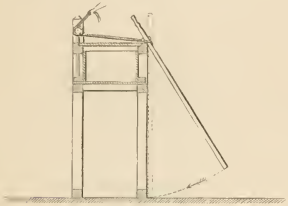
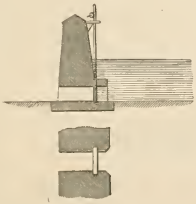


Fig. 718.



Through the batardeaux water passes by means of vanes sliding up and down in a projection of masonry, built at the foot of the wall; it is worked by a crab, to which access is given by means of a narrow wooden bridge supported by iron

Fig. 719.

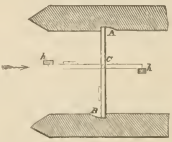


hooks. This is easily destroyed by the enemy, and it is better to make the wall stronger and to construct a vaulted passage through it leading to the work of the vane.

Fig. 720.

Such small sluices, however, do not give passage to a great mass of water at a time, and turning-gates are preferable for the "chasses." A gate A B turns round a pivot C, nearly but not exactly in the middle, so that the pressure on B C the greater side keeps it shut. A small vane *d d* cut through B C, may be raised either by hand or by a crab, and the surface pressed by the water becomes greater

Fig. 721.



on A C than B C, and the gate is thrown open when it is kept fixed to the hurters *h h*. To close it, the vane is let down, a little impulse is given to the gate, and the pressure of the stream soon shuts it. These gates easily get out of order.

Dams vary much in nature, and are made either of earth as in the field, or of masonry. When they are required to maintain the inundation at a constant level, waste-weirs are prepared on the whole or part of their lengths. The down side is made either at a small angle or of two arcs of a circle, to prevent the formation

Fig. 722.

Fig. 723.

of pits or the occurrence of accidents which might injure the work. Sometimes the dam consists of a vertical wall, and the water runs over an inclined plongee forming sally, and as the depth below should be equal to the height of the fall, a small ditch or hollow must be excavated. In some localities the weirs are like those which we have spoken of in Field Fortification.

SECTION VI.—Details.

(384). The execution of permanent works differs from that of field-works: it requires a long time to construct a fortress, and costs the State no small outlay, it is therefore important that the project and estimates should be carefully studied beforehand. It is a long and tedious task, and one which exclusively belongs to the province of the military engineer, so that we shall only say a few words on it.

The ground is represented on paper, at a proper scale, with the horizontal contours, the tracing is made on that plan. Every part of the fronts is discussed: the organization of the mines and of the water defences is prepared; the reliefs and the commands are also determined, and it is only after many attempts and trials that the plan can be satisfactorily settled. But this is not all, the deblais must balance the remblais. Both are valued approximatively by the prismatic or the centrobarique method, neglecting the foisonnement, since there is no inconvenience in making the parapets a little higher than they should be, if the earth has time to sink and settle. It is necessary that each part of a front, and if possible each face, should be constructed of the earth immediately before it, as the transport of earth from a distance occasions a loss of time and an increase of outlay. It is therefore after many trials that a satisfactory solution of the problem will be arrived at.

The plan or project being so far settled, the next step is the calculation of the the expenditure for the excavation, the transport of earth, the construction of masonry, parapets, &c., &c., so as to present an estimate of the total cost of the fortress.

It is only when this estimate is completed that the Government can discuss the propriety of executing the work.

With regard to the tracing on the ground, it is done by methods similar to those resorted to in the field, but with more accuracy.

Before concluding, we may add that in every country special laws prevent the inhabitants of a fortified town from erecting buildings that would hinder free circulation at the foot of the ramparts, or obstruct the space necessary for the defence and the communication. These laws also prohibit building, excavating, or planting outside the place, at such a proximity to the fortification as would afford cover to the enemy during a siege. The roads, canals, railways, &c., passing through fortifications are liable to certain restrictions, and these matters are usually settled by a commission consisting of military and civil engineers.

(384a). In order to compare the relative values of fortresses, Cormontaingne employed a method known as the "*scale of comparison.*" It consists in attacking

on paper, without taking accidents into account, the fronts to be compared: the besieger is supposed to carry on his approaches according to general rules, as he would before a garrison determined to defend itself, and to employ for each construction of batteries, trenches, &c., the average time which the experience of past sieges has given us; the garrison, on the other hand, is supposed to do nothing besides the ordinary fighting, and to make no sorties, mines, counter-approaches, coupures, retrenchments, &c. The duration of the defence forms the scale.

General Fourcroy* attempted to improve this method, but he fell into a great error: he compared places by their *moments*, namely the quotient of the number of days of defence by the cost of one front. Those days which he admits into his calculations as having the same value, it is in reality almost impossible to compare: the advance made and the loss suffered in a day of the first parallel, being widely different from those of the twenty-four hours employed in crowning the glacis or forming a lodgment on a breach.

The method of Cormontaingne may be employed advantageously: of two fronts costing the same, the better will be that which is capable of a longer defence; the less a front costs and the longer a defence it is capable of, the better it will be. But it should be understood that this method gives only an approximative idea, and that the duration of the defence is a *minimum*. Two very important items, viz., the energy and talent of the governor and the enthusiasm of the garrison and population, are overlooked.

This calculation of the probable duration of the defence for fortresses of different systems on various polygons, has had this inconvenience, that governors of places became imbued with the notion that they were not bound in honour to defend themselves beyond that time, so much so, that Napoleon complained of it when in 1809 he requested Carnot to write, "on the defence of fortresses."

* Fourcroy (Charles René de Ramecourt), born 1715, died 1791, was a General in the French Engineers, and a contemporary of Cormontaingne.

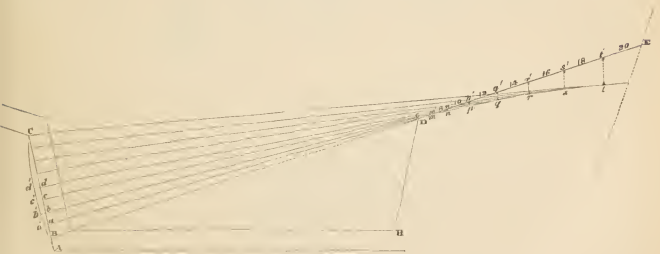
CHAPTER XXIII.

PRINCIPAL BASTION SYSTEMS.

(385). Bousmard (484), in 1797, published a system which possesses remarkable features. Having traced the enceinte of Vauban's first system, he divides the crest B C of the flank into eight equal parts, and the original face into the same number, being respectively 6, 8, 10, 12, 14, 16, 18, and nearly 20 yards in length.

The new faces will be composed of eight broken lines, obtained as follows: through the first division of the flank, and the opposite shoulder angle, draw a line and produce it as far as m, where it is met by the perpendicular drawn upon its direction from the first division of the face; through the second division of the flank and that extremity m, draw a line, which will likewise be limited in

FIG. 724.



n by a perpendicular dropped on it from the second division of the face; through the third division of the flank and n, draw a line, limited by the perpendicular dropped from the third division of the face, and so on. The flanks are also traced on a curve obtained by drawing from the angle A of the crests a perpendicular

on the first line, then a perpendicular on the second, and so on, so that every part of the face is flanked at right angles by the corresponding part of the flank. By this means Bousmard hoped to save the faces from the ricochet, and to mask their prolongation by the collateral ravelins in polygons superior to the hexagon. The breach cannot be seen by more than two guns; and he considered this of little importance, because the guns are chiefly needed to hinder the passage of the

Fig. 725.

ditch, which the whole flank can see. However, the ditch is not so well defended as before, and the curvature of the faces is too small to prevent ricochet.

His tenaille has flanks without either terreplein or banquette. Each of these contains a casemated battery for 4 guns, and on the vault a mass of earth rises high

Fig. 726.

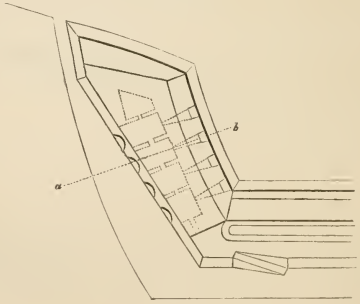


Fig. 727.

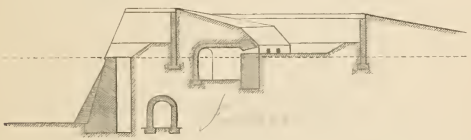
enough to protect the parapets behind, without preventing them from seeing the foot of the breach. The curtain only has a parapet for musketry.

This is an excellent outwork: the casemates are skilfully disposed, and their rear is protected by the shoulder angle of the bastions.

The main ditch is reduced to 20 yards, in order that the defenders may throw hand grenades into the lodgment of the enemy on the covered way; but as these lodgments are nearly 40 yards distant from the crest, it is doubtful whether grenades could be thrown so far.

The covered way is traced en cremaillère, and extends along the counterscarp of the main ditch. The traverses have the form of redans, and contain loop-holed casemates, from which a fire of musketry may be directed along the covered

Fig. 728.



way. At the extremity of each traverse a *pas de souris* establishes communication between the covered way and the main ditch, and each casemate is provided with a staircase, which communicates with the gallery of counterscarp, into which the defenders can retire; from that gallery they withdraw through a vaulted traverse erected along the passage of the double caponier. Bousmard calculated that this disposition would strengthen the defence of the covered way; but the casemates are so low that their fire cannot do much harm to the enemy on the glacis, whilst the enceinte is prevented from firing for fear of injuring the defenders exposed on the banquette of the traverses. Besides, it would cause a great outlay, on account of the masonry.

Between the two central traverses there is a re-entering place of arms with a revetted reduit.

The ravelin is detached beyond the glacis of the enceinte, so that the latter cannot be breached through the ditch of the former; and this is the distinguishing feature of this system. Its salient is obtained by describing an equilateral triangle on a line that joins two points respectively, taken on the crests of the faces of the bastion at 30 yards from the salients. The first part destined to form a bonnet has faces 60 yards long, measured on the sides of the triangle. The second part, traced obliquely to the first so as to be protected by it against ricochet, is terminated at 60 yards from the crest of the covered way of the enceinte. At its outer extremity the parapet turns at right angles to form a casemated traverse, so that each long branch constitutes an independent intrenchment. It is defended by a reduit, and to protect the scarps of the flanks of this work, a traverse is erected at the inner extremity of the long branches of the ravelin.

The ditch of the ravelin and that of its reduit are formed by the glacis of the enceinte, which is so produced outside that the depth near the salient is about 20 feet.

The gorge of the reduit is closed by palisades. Two loopholed galleries, easily destroyed by the artillery of the place, and whose fall brings down the terreplein of these works, are constructed all round the gorge of the ravelin and of its reduit. The vaulted passage of the caponier leads to the centre of the reduit, and also to those galleries, from which staircases lead to the terreplein.

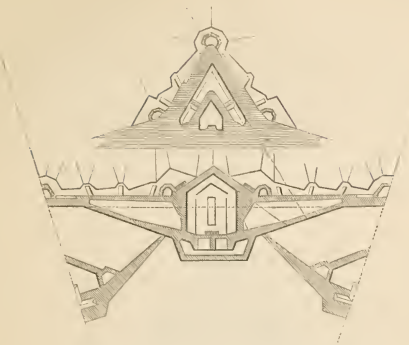
This ravelin renders practicable the concentration of troops in its rear for the purpose of making important sorties, but it is too far from the enceinte to be well defended; and the garrison itself, although skilfully protected against ricochet by the bonnet, is not a little exposed to the shots of the defenders behind.

The covered way of ravelin is disposed similarly to that of the enceinte, with traverses, gallery of counterscarp, with subterranean communication into that of the latter, with re-entering places of arms, and with revetted reduits.

A great defect of this system is that the ravelin and its reduit are liable to be taken by the gorge. It is chiefly remarkable for its skilful dispositions of detail.

(386). Chasseloup-Laubat (485) has proposed several systems (1805), and applied his principles in the construction of the fortifications of Alessandria. These works were destroyed by the Austrians in 1814. His method is a combination of Bousmard's and Montalembert's systems. It gives 580 yards to the front, and takes a perpendicular of $\frac{1}{8}$. The face of the bastions are bent lines: the salient part, 70 yards long, is traced on the front line, and the long branch is 160 yards in extent. The flanks are perpendicular to the line of defence, and defend the long branches, whilst the short ones, already secure against ricochet by their direction, are flanked by a caponier, which occupies the place of the ancient ravelin.

Fig. 729.



The salient of this work is 55 yards distant from the line of front, and the faces, 60 yards long, are directed on points at 55 yards from the shoulder angle of the bastion. The flanks are parallel to the perpendicular. The main ditch is 20 yards wide at the salient, and its counterscarp is directed on the shoulder angles of the caponier. In the wide portion opposite the shoulder angle of bastion, there is an interior glacis sloping downwards from the bastion as well as from the caponier, and protecting the masonry of these works.

The tenaille is similar to that of Bousmard, and the casemates are constructed for 3 guns. The covered way extends along the main ditch, and is not exposed to ricochet. Its redúits are casemated polygonal redoubts. The redoubts of the re-entering places of arms close the opening of the tenaille, so that the enemy cannot, from the glacis, breach the curtain as in Bousmard.

The salient of ravelin is 240 yards from the front, and the faces are directed on points at 100 yards from the shoulder angle of bastion. It is defended by a casemated reduit, and has a covered way similar to that of the main ditch.

In order to render the defence of the covered ways more energetic, Chasseloup recommends the construction of a double row of casemates on the rampart of the ravelin and of the bastions, the inner row to lodge troops, the outer one to contain guns firing through embrasures cut below the level of the crest of the glacis.

The bastions contain permanent retrenchments and defensive barracks. Although the revetments are higher than in Bousmard's, yet the ravelin and the reduit are exposed to the same danger.

(387). General Noizet (487) in 1822 altered Cormontaingne's tracing, and the modified system is now taught in the French military schools as the Noizet's tracing or modern system. The enceinte is nearly the same, except that the flanks are traced like those of Vauban. The ravelin, 45 yards more salient than Cormontaingne's, has an angle of 60°, which enables the bastions to see its glacis in flank and reverse. The faces terminate within 10 yards of the line of front, thereby affording a safe passage to the redoubt of re-entering place of arms, and permitting the flanks of the reduit of ravelin to see the counter-batteries. Each face has a coupure.

Fig. 730.

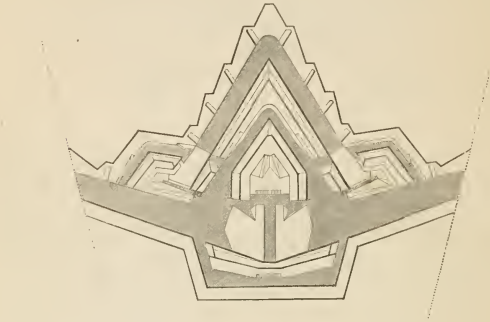


Fig. 731.

Profile along the ditch of ravelin

The reduit of re-entering place of arms is larger than in Cormontaingne; and the ditch of the interior face is well flanked by the bastion. It must, however, be observed that the exterior face is exposed to ricochet, which was not the case in the original tracing. The scarp contains a loop-holed gallery.

The opening of the ditch of the ravelin is closed by a mask of earth and masonry erected between the coupures of the ravelin and the reduit of place of arms. Its inner edge is formed by the countescarp of the main ditch, which is produced as far as the ravelin. The surface of this mask has a double slope which enables the

bastion to see the whole ditch of ravelin. Before the mask, and separated by a small ditch, is a caponier of earth forming a covered way and glacis. The masonry of the bastion is thus well protected. The shoulder angles are covered by traverses constructed at the extremities of the tenaille. The covered way is of the same nature, but the tracing of the traverses and their crochets is complicated by geometrical constructions.

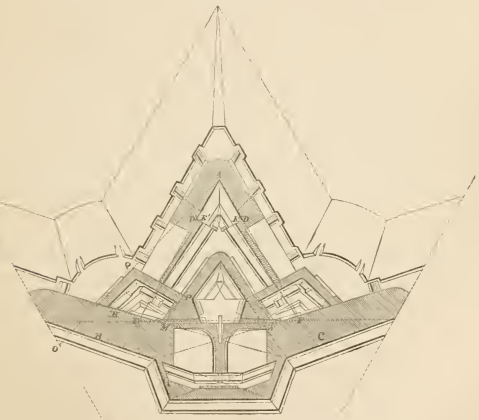
The command differs little from Cormontaingne's. Noizet gives an increase to the salients in order to protect the faces against ricochet.

All these modifications are decidedly improvements; the enceinte powerfully flanks the outworks, and the communications are safe; but as the alterations bear merely on points of detail, it is doubtful whether they would seriously increase the duration of a siege.

(388). Dufour's system (488).

The enceinte is traced as in the modern system; the ditch is 30 yards wide at the salient of the bastion, and the counterscarp is directed on the shoulder angle. The ravelin is considerably altered by the erection of a *cavalier* or bonnet, 24 feet high, at its salient. This mass is destined to protect the artillery of the ravelin

Fig. 732.



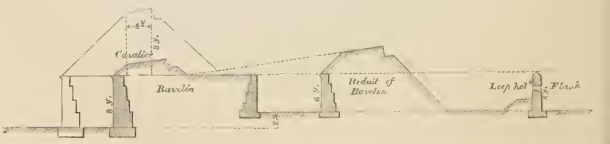
against ricochet fire, and General Dufour calculates that, by giving to the faces of ravelin a slope of 3 feet in their length, the terrepleins will be perfectly secure from ricochet for a length of 270 feet. To trace this outwork, the primitive triangle A B C is constructed as in the modern system. Take A D = A D' = 45 yards, and draw the perpendiculars D E, D' E' = 8 yards. In joining the extremities E, E', of these perpendiculars to the points F, F', where the primitive triangle intersects the counterscarps, the master line of the ravelin is obtained.

The parapet of the cavelier is only 4 yards thick, and is supposed to be sufficiently strong to resist ricochet; there is no rampart, the banquette is destined for musketry, and its slopes descend to the terreplein of the ravelin. The ends are retained by walls sufficiently thick to bear the pressure of the remblai, but which may easily be destroyed by the artillery of the place, should the enemy attempt to form a lodgment. Two flights of steps placed at the extremities of the faces lead to this banquette. General Dufour calculates that after the breach, the parapet of the lodgment will be 3 yards lower than that of the cavalier, and to render its establishment difficult or even impossible, he puts in this cavalier some beds of stones or fragments of masonry, which he covers with 2 to 3 yards of earth to protect the defenders from the splinters.

The *ravelin* is 22 yards wide, 2 yards wider than in the modern system, to afford room for the construction of ramps, 3 yards wide, and at slope $\frac{1}{4}$ for the passage of artillery. The escarp is 24 feet high. The ditch 20 yards wide, has its counterscarp parallel to the sides of the primitive triangle, and its bottom is 6 feet above that of the main ditch. The command of the ravelin over the covered way is 6 feet next to the salient, and 3 feet at the extremities of the faces.

The *reduit of ravelin*, is separated from the ravelin by a ditch 10 yards wide and 6 yards deep, its bottom being 6 feet above that of ravelin, and 12 feet above the main ditch. The faces are parallel to those of ravelin, and the gorge is traced parallel to the curtain on the line M N that joins the points of intersection of the counterscarps of the main ditch with that of the reduit. The flanks, 25 yards long, are traced in taking 30 yards off the face, and 20 off the gorge, as in the modern system. This reduit has no rampart, in order to leave no available space to the enemy; the slope of banquette descends to the terreplein

Fig. 733.



which is on a level with the ditch. The flanks are mere loop-holed walls 6 yards wide, and 3 feet thick; the loopholes are at 9 feet from the ditch, and a banquette enables the garrison to use them. Each wall has a door, wide enough for the passage of artillery, leading to the ditch; it is closed when the enemy has taken the ravelin. As these flanks cannot be seen from the lodgments, they have nothing to fear from artillery.

This disposition of the reduit permits the defenders to hold the redoubts of the re-entering places of arms, after the fall of the former, since their terreplein cannot be seen.

The reduit has a command of 6 feet over the ravelin at the salient, and $1\frac{1}{2}$ feet at the rear, so that its plane of defilade passes above the lodgment of the cavalier.

The *covered* way is 10 yards wide, and has four traverses. The three first are 3 yards thick, and the last 6 yards. The first is traced as usual, the second is also oblique, in order to enable the cavalier to see its exterior slope; its position is found by dividing into 3 equal parts the length of the counterscarp contained between the first and last traverse, and directing the crest to 10 yards from D. The last, however, can only be traced after the re-entering place of arms. The pan-coupé at the salient is 10 yards long. The crochets are made as in Vauban's, and are revetted; they serve for the passage of infantry, whilst artillery ascend by the ramps constructed at the gorge of the places of arms. There is no palisading except at the salient.

In order to close the tronée of ravelin, Gen. Dufour unites the coupure of ravelin with the *reduit of re-entering place of arms*, so as to form only one work, the escarp of which is protected by a glacis erected in the ditch. To trace this reduit, join the salient A of the cavalier to a point O on the capital of the bastion, at 25 yards from the flanked angle: it gives the counterscarp of the exterior face, while that of the interior one is obtained by drawing the perpendicular P Q to the side of the primitive triangle. Parallel to the counterscarps and 7 yards in rear are the escarps.

The cavalier protects the exterior face against ricochet: the interior one is covered by a bonnet at the salient, 3 feet higher than the parapet, and by a traverse of equal command along the face and in the prolongation of the parapet of the ravelin. The bonnet covers 3 guns, destined to flank the ditch of the ravelin, and to contribute, with those on the bastion, to oppose the construction of batteries at the salient of the covered way. The traverse covers 2 guns that sweep the terreplein of ravelin. To prevent the enemy, once established on the cavalier or in the reduit of ravelin, from taking the exterior face at reverse, this face has a slope of 5 feet to the rear, and the parapet of the interior face has the same command at the salient of the reduit of the ravelin. The rampart of the interior face must also slope to the rear to insure the defilade. The escarps are

18 feet high, and the parapet has a command of 9 feet. The rampart, including the interior slope, is 10 yards wide, and is supported along the interior face by a revetment, which the defenders can easily destroy by artillery if the enemy attempts to make a lodgment: on the exterior face, which does not present a favourable position to the enemy's batteries, an earthen slope is sufficient. As in the reduit of ravelin, the terreplein is on the same level with the ditch. A large ramp along the revetted face leads from that terreplein to the rampart. A postern, on a level with the terreplein, leads to the ditch, and from that ditch a ramp leads to the covered way. Another ramp at the gorge of the reduit, leads from the main ditch to the terreplein, thereby affording a short passage to artillery from the place to the covered way. The revetment wall of the extremity of the interior face is produced to the main ditch in order to prevent surprise, and to protect the work against the musketry fire from the reduit of ravelin. A gate opposite the ramp enables the garrison to communicate with the ravelin.

In the ditch of the ravelin, a traverse forming glacis protects the escarp of the reduit of the place of arms against breaching batteries, which the besieger may construct at the salient of the covered way. A passage of 3 yards is left between this glacis and the escarp of the ravelin to prevent the enemy from escalading the latter, and to enable the garrison to communicate between the ditch of the ravelin and that of its reduit. A strong gate closes the passage, which is covered by the shoulder of the cavalier, and a little gallery constructed under the traverse flanks that gate.

The *re-entering place of arms* is traced from the point H, the intersection of the counterscarps of bastion and ravelin, as a centre with a radius 10 yards longer than H Q. Two circular sally-ports lead to the glacis. The crest of the glacis of the bastion and of the re-entering place of arms, has a command of $1\frac{1}{2}$ feet over that of the glacis of ravelin. The enceinte in this system can sweep the re-entering place of arms with its guns.

This system possesses many advantages. The besieger cannot breach the enceinte from the crowning at the salient of the covered way of the ravelin; the reduit of the re-entering place of arms is large and well calculated to dispute the possession of the ravelin, and as it does not mask the fire of the bastion, the enceinte can sweep the glacis; the ditch of that work is flanked on both sides, viz., by the bastion and by the flanks of the reduit of the ravelin; the narrowness of the terreplein of the outworks does not afford room to the besieger for the construction of batteries, and he must crown the covered way of the bastion in order to breach the enceinte, a great advantage for the defence, since the garrison will have only one breach to defend. The defence on this system is calculated to last 40 days. The communications are easy and practicable to all arms, thereby facilitating the sorties. The enemy, compelled to construct direct batteries, will

consume more ammunition, he will besides lose time and labour in giving his trenches a great command, since the place has a great relief, and the defence being simplified will become more energetic. The outlay is not greater than in the modern system, because if on the one hand the mass of the cavalier and an increased relief necessitate greater remblais, on the other there is a saving of 2000 cubic yards of masonry.

It is to be remarked, however, that the cavalier prevents the defenders from placing artillery at the salient of the ravelin, where its presence is so important, and that the reduit of the ravelin has no room for guns.

(389). *Choumara* (489). In 1827 Choumara published some "Mémoires sur la Fortification," a new and enlarged edition of which was reprinted in 1847. It is therefore to the former date, and even to 1824, when his memoires were communicated to the corps of Engineers, that this remarkable volume should be referred. This priority of date is important, as between 1827 and 1847 spurious imitations and plagiarisms were brought before the public.

This work has not been translated into English, and should it be, but few officers of the line could thoroughly understand its contents, and appreciate its great value, through want of a knowledge of that branch of mathematics on which the drawing of plans is based. To those of my readers who are already conversant with military drawing, and who are acquainted with the elementary principles of Fortification, I cannot too strongly recommend a serious perusal of these *Mémoires*, for the science at the present time does not extend any further.

Instead of offering a new system, as his predecessors too often did, Choumara proposes new and general principles, applicable to all the systems either past, present, or to come.

(390). The two chief principles are:

1st. The reciprocal independence of the parapets and the escarps.

2nd. The construction of an interior glacis in the ditches.

That which distinguishes Choumara from other writers on the science, is the objection he has to supersede everything by the introduction of a new system; his constant endeavour is to modify the fortresses already extant, in order to increase their power of resistance. He always affirms that he has no system. In fact he has given principles, deduced consequences therefrom, and generalized them; and, although he has grouped together a few combinations susceptible of presenting a formidable *ensemble*, yet he by no means considers them as an indivisible whole; these combinations, he says, can be adopted either partially or wholly, according to circumstances, and the engineer may select the special improvement required for the particular fortress entrusted to his charge.

Starting from the two principles above mentioned, he leads us to the discovery of various combinations arising therefrom, which may be employed in the

organization of a place from the most simple case, that of an enceinte without either outwork or interior intrenchment, to the most complicated one, that in which, having at disposal both space and money, a complete fortress can be erected, having—

1st. An enceinte, with an interior glacis in its ditch.

2nd. A general intrenchment against an exterior attack, composed of the combination of the military buildings with bastioned towers, forming themselves good bomb-proof barracks, and so disposed as to favour the interior defence, should the enemy enter the place.

3rd. A ravelin, with a ditch and its interior glacis.

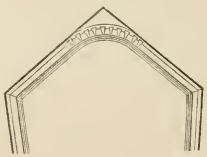
4th. Some redoubts in the salient places of arms of the bastions and ravelins, whose covered way also contains an interior glacis, forming at will a basin of inundation, that is calculated to oppose the construction of the batteries destined to breach the salient redoubts, to submerge the descents into the ditch, the mines, and even the trenches on the exterior glacis, thus transformed into a deversoir.

(391). A striking feature of Choumara's principles is the superiority which their application tends to restore to the defence over the attack. With him, in fact, the escarps are only destined to prevent an attack by surprise; they are the permanent part of the fortification, whilst the parapets constitute the temporary or moveable part. The masonry forms the enclosure of a field of battle, in which the garrison will fight at advantage, throwing up earthen parapets now in one direction, now in another, following step by step the progress of the besieger, counter-attacking him by the construction of new parapets varying with the circumstances, and assuming an active part instead of a passive one.

Let us pass in review some of the consequences which we may derive from the first principle.

(392). The parapet may be made circular at the salient of the bastion, so as to fire on the approaches carried along the capital.

Fig. 734.



The advantages of fronts in straight line (305) are at once obtained in tracing the parapet on directions whose prolongations are intercepted by the ravelins.

Choumara recommends the employment of the space intervening between this

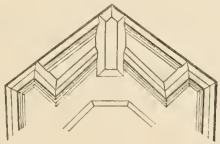
Fig. 735.

parapet and the escarp, for a chemin des rondes for musketry; and in order to protect its defenders a bonnet or a traverse is constructed at the salient.

Fig. 736.

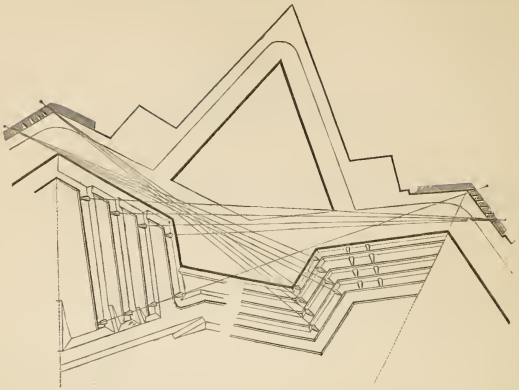
The parapets of bastions may be traced perpendicular to the ditch of the ravelin, which they flank more effectually, whilst they afford new flanks from which the lodgment of the besieger can be seen, and fire directed against his counter-batteries.

Fig. 737.



(393). The flanks, being withdrawn further from their escarp, can be made longer, and receive more artillery than the enemy can place in his counter-batteries. Thus a line drawn from the last gun of the crowning to the shoulder of the escarp, will limit the improved flank. The curtain itself, being drawn in, will permit the construction of flanks from which fire can be directed on the approaches.

Fig. 738.

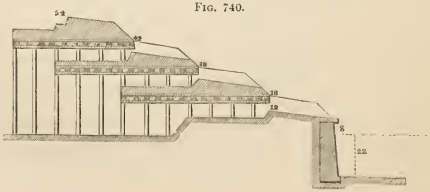


(394). The defence may even assume an enormous superiority of fire if several flanks are placed behind one another, as represented in the left bastion, and in this profile. This alteration, Choumara assumes to be practicable, even during the siege, provided earth has been reserved for the purpose.

Fig. 739.

Additional enceintes may be formed in the manner represented in the last profile, and if timber is abundant, a system of blinded batteries, giving several tiers of

Fig. 740.



guns, may be organized all round the enceinte; or at those points where an overwhelming fire of artillery is judged necessary, as in the right bastion (fig. 738).

The parapet of the bastions and ravelin may, in fact, assume any such traeing as the requirements of the defence render most advisable.

Fig. 741.

Fig. 742.

Fig. 743.

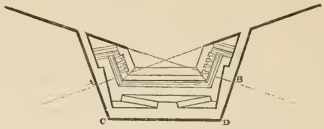
Fig. 744

Fig. 745.

Fig. 746.

(395). All these improvements, applicable to any system, do not imply any alteration in the masonry of the place. When, however, the engineer is at liberty to alter the enceinte, Choumara recommends the withdrawal of the original curtain A B as far as C D, the extremities of the retired flanks: owing to this modification, the tenaille can be constructed so as to mount artillery on its flanks;

Fig. 747.



and the parapet of its faces, besides giving musketry fire on the covered way, can protect the defenders of the flanks against ricochet. This tenaille is only revetted along the face, and that part of the gorge which is parallel to the flanks of the bastions. It may also be casemated so as to receive additional guns.

(396). The construction of a glacis in the ditch prevents the besieger from breaching the enceinte from the salient of the covered way, and closes the trouée

Fig. 748.

of the ravelin. In order to prevent the enemy from advancing in sap along the ditch of the ravelin to crown this glacis, it may be constructed in the shape of a

Fig. 749.

traverse. Both profiles may be adopted simultaneously; the former at the salient of bastion, the latter along the gorge of the ravelin and faces of bastion.

(397). With regard to the erection of new fortresses, Choumara has proposed important alterations in the ordinary methods, and we represent (fig. 752) the outline of a front in which these modifications are indicated.

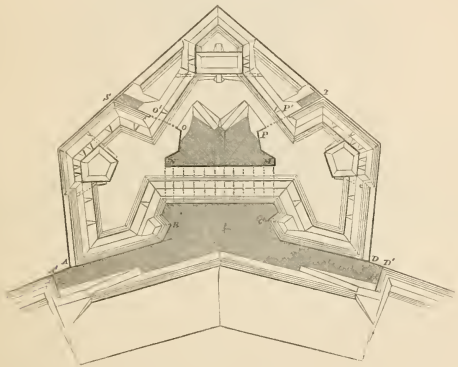
Setting aside the defence by musketry alone, he recommends the lengthening of the front to 500 or even 600 yards, in order to obtain capacious bastions, the

only ones which can be properly retrenched: it is for the same reason that he gives to the curtain the minimum length. He strongly insists upon the chemin-des-rondes as destined to prevent the parapet from falling, and rendering the breaches practicable.

At the salient of the bastions he establishes casemated traverses 20 feet high, to arrest the ricochet: they can be destroyed when abandoned by the defence, and they give fire on the capital as well as on the lodgment at the salient of the ravelin. Such traverse may be provided with a parapet on the top. They occupy less room than the twelve ordinary traverses which the faces of bastion would require.

(398). The retrenchments in the bastions are organised in such a manner that the capture of one bastion is not attended with the fall of the place. Every bastion has a retrenchment towards the interior of the place, consisting of a bastioned front A B C D, with unrevetted countescarp E H K, and a ditch 14 feet deep before the curtain and 24 feet at the extremities E and H. A glacis and

Fig. 750.



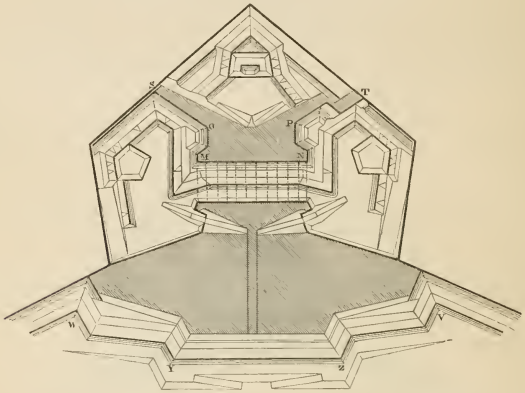
narrow covered way surround the ditch. The curtain of the enceinte in D D', A A', has no parapet, and the wall is loopholed to procure a view of the dead angle between the flanks and the tenaille.

The bastions of the retrenchment have orillons which protect the chemin-des-rondes of their flanks. Under the curtain, several casemates 60 feet by 20, serve

as magazines or barracks. They are 2 feet above the bottom of the ditch, and can contain 500 men. Each bastion can thus contain its ammunitions and provisions, and constitutes an independent work. A subterranean passage under the curtain establishes communications between the various bastions of the place which can mutually support each other.

As for the bastions of attack, a retrenchment towards the exterior is necessary, and Choumara provides for it. A ditch M N O X P, 14 feet deep, in rear of the curtain B C, is revetted by a wall which from O to O′ and P to P′ is built under the terreplein of the bastion, and connected with the wall S O′, P′ T of the chemin des rondes. It constitutes a bastioned front with orillons, and the defence

Fig. 751.



can complete it when the besieger has begun his attacks and occupied the salient of the covered way of the ravelin. If the earth from the ditch is not sufficient, some is taken from the interior bastion, now useless, the wall of which only is left standing. This transformation, according to Choumara, will occupy 150 men during 3 days.

A second retrenchment W Y Z V, not revetted, is constructed in rear.

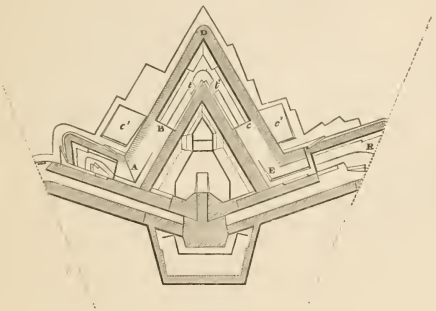
The outlay in the construction of these retrenchments does not increase the total cost of a fortress more than one-eighth of Cormontaingne's tracing, and yet

the defence may be prolonged 24 days, viz., 9 days for each of the exterior retrenchments, and 6 days for the simultaneous attack of the isolated bastions.

(399). The main ditch is widened to 50 yards, in order to give room for a glacis that will leave a 16 yards passage between its crest and the escarp.

The tenaille is traced as described before.

Fig. 752.



The ravelin has, like the bastions, a chemin des rondes, a parapet with flanks, and a casemated traverse in capital. The gorge is not entirely revetted, and possesses a wide ramp destined to permit offensive returns. Coupures may be organised.

The covered way consists of two distinct parts. The first A B C D E slants from the counterscarp to the exterior, forming glacis, and also from the counterscarp of the main ditch towards the salient, where it forms the ditch of the salient reduit. It covers the escarp of the ravelin against the batteries of the crowning. The second part is an ordinary covered way with glacis, which contains caponiers C′, C′, and no traverse.

The reduit of the re-entering place of arms is provided with a chemin des rondes, and a circular parapet; the counterscarp is not revetted. Sometimes the two adjacent reduits are replaced by one reduit of greater dimension, as in R. The salient place of arms has a reduit of the same nature, the faces of which are protected against enfilade by traverses t, t'. The communications consist of ramps practicable to all arms.

(400). These modifications are calculated to protract the siege. It is easy to

see that the saliency of the redult B D C increases the perimeter of the first parallel by nearly 300 yards, and as this redult requires counter-batteries to be silenced, the second parallel will not be completed as soon as usual. The progress of the saps will be slackened by the artillery of the defence no longer destroyed by ricochet; and the construction of the third parallel will also be retarded. The approaches against the bastion cannot be commenced until after the salient redults are taken; and the crowning of the salient of the covered way, also rendered difficult, will not, according to Choumara, be finished before the thirty-seventh night. It is now, however, that the difficulties which the besieger must surmount become serious. To take the place, he will have six distinct breaching batteries to construct: 1st, against the salient redults; 2nd, against the redult of the re-entering place of arms, and the ravelin; 3rd, against the bastion; 4th, against the first exterior retrenchment; 5th, against the second exterior retrenchment; 6th, against the isolated bastions; and, as he cannot construct them simultaneously, but is obliged to erect them in succession, the defence will be considerably protracted.

The breaching batteries against the salient redults would be exposed to too great a fire from the collateral works, from the redults of the re-entering place of arms, from the bastions, and even from the work itself, if constructed on the glacis, as usual: they must be erected in the ditch itself. The ravelin is breached by a battery constructed on the salient redult, and the redult of the re-entering place of arms by a battery erected opposite its salient. As this redult is seen at reverse from the ravelin, the defence may, by an offensive return on the ravelin, oblige the enemy to abandon the former.

The breaching batteries against the bastion, as well as the counter-batteries, must be constructed on the interior glacis of the ditch, and the overwhelming fire to which they are exposed affords a fair chance to the defence; in fact, there is scarcely room for more than six guns in the counter-batteries. However, supposing the bastion of attack carried, there remain still the exterior and interior retrenchments. Choumara calculates the duration of the siege at 112 days: it is, perhaps, too much, yet there is no doubt that the defence will be very much lengthened, nearly three-fold, whilst the expenditure is not much increased.

We cannot follow Choumara in all the details he gives. Let it be sufficient to say, that he has rendered to the defence its former superiority over the attack, and that by applying part of these modifications to the old fortresses, the very worst of them evidently become superior to the best tracing hitherto known. To earthworks he chiefly entrusts the active part of the defence; and the recent events in the East speak so loudly in favour of his ideas, that it is needless to dwell longer on their vital and obvious importance.

(401). General Haxo (490) did not publish his system, but in 1826 he had

a plan of it engraved, which he distributed to some French engineers on condition of not rendering it public.

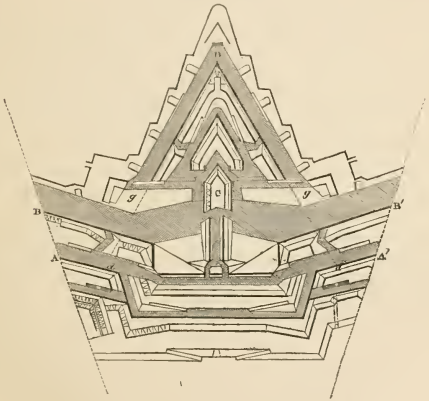
The front is 360 yards long. The perpendicular is only $\frac{1}{9}$, and the faces $\frac{1}{7}$ of the front. The flanks are perpendicular to the lines of defence. The bastions contain interior retrenchments entirely separated from the rear by a ditch. A chemin des rondes surmounts the scarp of the enceinte. In the bastions the parapet is removed from the wall so as to increase the length of the flank. In the left one, which is full, stands a cavalier, or high bastion, that carries two tiers of guns, the lower of which is casemated (à l'Haxo, 379).

The tenaille is not revetted, and it has flanks that can mount three guns.

The salient of the counterguards is formed by the intersection B B′ of the capitals, and a line parallel to the front, and at 45 yards from it: their faces are 125 yards long, and their flanks parallel to the perpendicular. They have a chemin des rondes, a coupure, and a casemated battery in capital.

The main ditch is 20 yards wide. The ravelin is traced by measuring 17 yards off the shoulder angle of bastion to *d*, and describing from that point as centre, and radius 250 yards, a circle which intersects the perpendicular in D, and

Fig. 753.



joining D *d*, D *d*′. It is thus made very salient. A casemated traverse is in capital, and coupures are cut across its faces. In rear is a reduit of the ordinary

outline, and behind it a casemated caponier or bastionet, the roof of which carries ten guns.

The counterscarp of the main ditch is produced to within 10 yards of this bastionet, and in front of it slants a glacis g, g' which closes the ditch of the ravelin and that of the reduit. A double caponier in the main ditch leads to the bastion, and is joined to the flanks of the counterguards by an interior glacis. The covered way contains traverses as usual: the salient place of arms has a casemated redan for a reduit. The reduit of the re-entering place of arms is also casemated: one of its faces is perpendicular to the counterscarp, the other parallel to it.

This tracing, in which Haxo has borrowed much from Choumara, and in which he has introduced a bastionet that reminds us of the caponier of Montalembert, is superior to that of the modern system, and yet not much more expensive than a front of the latter provided with permanent retrenchments. Its siege is calculated to last fifty days, and there are five distinct periods of breaching batteries; 1° against the reduit of the salient place of arms and the ravelin; 2° against the reduit of the re-entering place of arms, the coupures and the redoit of ravelin; 3° against the bastionet and the counterguard; 4° against the retrenchment; 5° against the bastion.

The masonry is skilfully concealed from the views of the distant batteries, and the chemin des rondes prevents the fall of the parapets. The command of the high bastion, 53 feet, interferes seriously with the defilade of the saps. The flanks of the enceinte have a good length, and those of the tenaille are well protected by the counterguards. These are judiciously traced, well flanked, and defend the ditches of the ravelin, reduit and bastionet, &c. Their coupure, however, appears useless, because it can be breached at the same time. The retrenchments in the bastions are not good, because they diminish the length of the flanks. The great saliency of the ravelin is well calculated to take at reverse the approaches on the covered way of the bastion. The bastionet sweeps the interior glacis, and powerfully co-operates with the flanks of the inner works to impede the construction of the counter-batteries. In the covered way the tracing of the re-entering reduits is good, and the casemated batteries are an excellent model, for the details of which we refer to 379.

(402). It is now time to forewarn military students of a mistake into which they may easily be led. It is not in learning how to draw a great number of systems that they will acquire useful information. Let them peruse the details of several sieges, for this, above all, will benefit them. It would indeed be a difficult task to stuff one's memory with the never-ending systems daily proposed.

We have examined these systems which are universally recognized as the

best, and intentionally left aside a great many which have for a time attracted public notice.

It is not long since new systems were proposed in this country by Messrs. Bordwine and Fergusson; in Holland, by Major Merkes; in Prussia, by Major Wittich; in Spain, by Colonel Herrera Garcia, &c. &c.

If a student will venture into more systems, let him investigate these as well as those to which allusion is made in our concluding chapter. He will soon grow tired, and will perceive that they are not so much distinguished from each other by any essential difference as by their authors' names. Every one who has written on Fortification has given at least one system of his own; three, however, is the favourite number. Marchi, an Italian engineer, in 1599, has, indeed, in a folio book, offered 161 different constructions, which he declares to be his own, and laments the loss of others that were stolen from him!

Engineers, officers, architects, professors of mathematics, students, and even pupils, all have claimed to be masters of an art, the elements of which they did not possess. The claim was easily set up, since by taking the straight line and the curve an infinity of combinations are to be made. Some have fancied that by multiplying the flanks they would attain their object; the most moderate have proposed three flanks, some four, others six, &c. Some will have two enceintes, others cut their works into a number of small parts, hoping to strengthen the system by increasing its complexity. They all forget the cost, the force of the garrison, and the provisioning; and each will assert that a fortress constructed according to his system is impregnable.

The outline of a system is undoubtedly an essential point, but it is not all. A determined garrison, ably commanded, will perform wonders even behind a wretched outline. Metz, in 1553, had but a single wall and rampart, and a dry ditch without bastions, yet Charles the Fifth, with 100,000 men, could not take it. The Castle of Mouzun, in Arragon, a mere barrack, garrisoned by only 100 French soldiers, resisted (in 1814) 3000 Spaniards for four months and a half! Vienna, in 1683, resisted three months the efforts of the Turks; Candia stood out against them ten years; Silistra with a Mussa Pacha, and Kars with a Williams, are still in every one's mind. Let us therefore beware of placing implicit confidence in any of the systems alluded to, and instead of attempting to build new fortresses, let us begin by improving the old ones, whenever necessary.

Alluding to the great number of systems, General Prevost Vernois says: "If we take into consideration the numberless systems of fortification which the human mind, or, if preferable self-complacency has invented, and which are with very few exceptions nearly all equally absurd, we shall soon be convinced that nothing is more difficult than to produce a useful and rational innovation. So

difficult is this art, that no one can reach the summit: even the most vigorous minds require rest during the ascent. It requires an eye like that of Vauban or of Napoleon, penetrating as the eagle's, to find on a frontier the strategic point; since such point is essential to a permanent fortification, and ought to be held by those on the defensive of whatever nature and however numerous the movements of the enemy may be. The strategic point being chosen, it remains to determine the kind of fortification which is best adapted for it; for there must be some plan of occupying this site preferable to any other; and this necessarily depends on the configuration of the locality. The best adaptation is written on the soil; but every one has not the gift to read it: we repeat, that without doubt, fortification is the most difficult of arts. The thorough engineer sees his fortress completely modelled on a plateau, a hill, a plain, or on a rock, just as a sculptor sees his statue in a block of marble; nay, more, he also makes the best of nature's resources. We have twenty sculptors of the first rank, and yet the work of ages has given birth to only one Vauban.

"The most difficult of all arts," says Fontenelle, in his eulogy on this great man, "are those whose object is change, since this does not afford to men of ordinary capacity the convenience of the application of certain fixed rules, but demands at every moment the natural and improved parts of a lofty genius.

"This is all the more worthy of remark, because all the efforts of Vauban's successors have been directed to the imposition of types on us, and to reduce the art of the engineer to fixed rules and to processes of descriptive geometry. Destitute of the power of being engineers, they are desirous of making themselves savants. Now although descriptive geometry can teach the way to apply a plan of fortification, such as it is, good or bad, to a given locality, when certain conditions are given, yet it will never supply the means of determining what plan is the best and most suitable.

"In painting and sculpture, fashion, caprice, the desire of varying combinations, and of exhibiting new ones, can lead artists into not a few vagaries; but these aberrations will not be of long duration; they are always brought back to truth by a comparison of nature's objects with their representation. Now nature affords no perfect model of a fortification, none which can serve to correct our errors. If a military engineer is carried away by the most extravagant whims, there is nothing to point out to him their absurdity. People do not understand it; engineers generally profess the most sovereign contempt for every new system which deviates from the teaching of the school: on the other hand, there always exist in large assemblies, a very large proportion of idleness, indifference, carelessness, inaptitude, &c., and the indolent are naturally the prey of active working men."

CHAPTER XXIV.

MONTALEMBERT AND CARNOT.

(403). Despite all the improvements made in the bastioned system of fortification since the time of Vauban, there are yet many important defects which have induced some engineers to renounce the bastion system altogether. They justly complain that:—the ramparts and the interior of the place are much exposed to vertical and ricochet fires, which ruin the artillery of the defence before the enemy reaches the covered way; the reverse and ricochet fires render the flanks of the bastions almost untenable, although it is on them that the defence of the ditch and breach rests; the communication between the enceinte and the outworks is badly organized, and renders difficult the sorties and offensive returns; the ditches of the outworks form openings through which the besieger may breach the enceinte from a distance; the parapet falls down at the same time as the wall when the breach is made; the interior intrenchments are very difficult to construct at the moment of need; the labour necessary to put the place into a state of defence and to keep it so during the siege is dangerous, exhausting and often impossible for the garrison to accomplish.

SECTION I.—Montalembert.

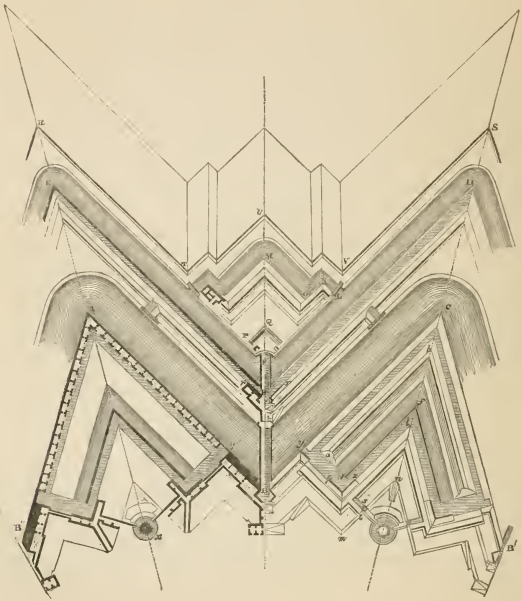
At the head of reformers is Montalembert (480), and although his systems have not been adopted, yet they form the base of the works constructed in Germany since 1815. We shall therefore say a few words on them.

The chief object of Montalembert is to prevent the besieger from opening a breach, by directing against him a superior fire of artillery whenever he attempts to erect counter or breaching batteries. His fortresses may be called immense batteries.

(404). *First system.* In 1776 he proposed to replace the bastion outline by the tenaille tracing. The name of *perpendicular fortification* is given to this system, because the faces of the re-entering angles are perpendicular to each other.

As the salient angles cannot be less than 60°, it is impossible to enclose a space with less than 12 salients; with a greater number of tenailles, the salient angles become more and more open. Montalembert has not given any formula for the tracing of his systems, but he has published elaborate plans sufficiently accurate to give a complete idea of his methods. The following data will enable the student to construct the outline.

Fig. 754.



The tenaille has faces A B = B C = 250 yards in our example, but their length may be increased with a range of musketry superior to that distance. The salient here = 60°.

This enceinte B″ A B C B′, consists of a casemated gallery, one story high only, for artillery and musketry.

The main ditch, 36 yards wide, is parallel to it. It is flanked by a casemated battery y B y' having two stories for musketry and artillery, besides a platform on which artillery may be placed. It occupies 40 yards along each face of the re-entering angle, and also flanks the rear of the gallery. Beyond this ditch, which Montalembert supposes wet, stands a general couvre-face or counterguard E H D, 30 yards thick, consisting of a remblai for infantry and a loopholed wall. It is intersected by coupures. A wet ditch, 18 yards wide, separates it from a covered way of 12 yards, and is flanked by a casemated battery r H r', of two stories for musketry and artillery, which also defends the rear of the loopholed wall, the faces of this casemate are 20 yards long. To defend the long branches of the covered way, and act as a reduit of re-entering place of arms, a lunette is traced: the gorge F L = 100 yards, and the flanks L N = 20 yards, N O = 22 yards; the wet ditch and covered way surround it, and are of the same dimensions as those for the counterguards, except round the flanks, where the ditch is not more than 10 yards wide. The ditch along the face is flanked by a casemated battery N O, two stories high. Inside these lunettes, a reduit having faces P Q of 25 yards, defends the terreplein; it is a loopholed wall rendered bomb-proof by arches, and is preceded by a small ditch.

The covered way has no traverse and no palisades.

Inside the general enceinte B″ A B C B′, Montalembert constructs for every salient a special counterguard a b of earth, 25 yards thick, the crest of which is parallel to and 25 yards in rear of the enceinte, and measures about 145 yards in length. A wet ditch 12 yards wide, defended by a loopholed wall d f extends in rear of the counterguard.

Eight yards behind this ditch is the exterior slope h z of the interior retrenchment, which turns at a right angle to join the great battery B y'; the foot m n of its rampart is at 30 yards from h z. A casemated battery for artillery and musketry z z', two stories high, and with faces of 20 yards, flanks the wet ditch in rear of the counterguard and the dry ditch that extends between its extremity and the interior retrenchment. At last a tower X, 11 yards in diameter and containing 24 guns in two stories, serves as a reduit. Its centre is at 30 yards from the foot of the rampart m n. A loopholed wall runs between the tower and a casemated traverset established on the rampart, and defends the terreplein. A small ditch s is cut across the rampart before each traverse.

The commands of these various parts are marked on the following profiles where x x represents the level of the country. The vaults of the casemates are pierced with cylindrical holes for the passage of smoke, and in the great casemate y B y', little chambers are constructed for the infantry, under the floors of which

FIG. 755.

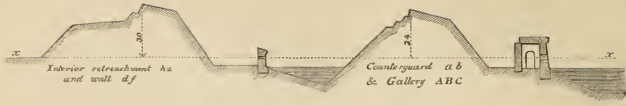


FIG. 756.

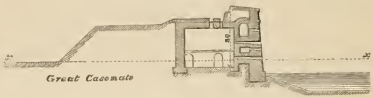


FIG. 757.

FIG. 758.

FIG 759.

the embrasures for guns are cut. As for the tower of this system, we shall have to enter into further details respecting it hereafter. With regard to the communications, the three casemates y B y' and $z\,z$, $z'\,z'$ communicate by subterranean passages: a postern leads from the place to the interior of the great casemate, and two posterns to each casemate $z\,z$. Ramps lead to the rampart of the interior retrenchment, and access is given to the inner counterguard and the gallery of enceinte by a door in casemate $z\,z$. A postern leads from the re-entering angle of the great casemate to a bridge across the main ditch, from which the counterguard is reached. On right and left, the passage continues through the casemate r H r', from thence a bridge leads to the terreplein of the lunette. A postern under the face of the lunette leads to the covered way across a bridge.

The bridge across the main ditch is constructed on two walls flush with the water and provided with banquettes. Should the bridge be destroyed by the besieger, the communication is not interrupted, and as it may easily be inundated the enemy cannot make use of it.

Fig. 760.

(405). The partisans of this system most particularly insist upon the advantage which the defence acquires from the four distinct enceintes, the general counter-guard and its wall, the casemated gallery with its inner counterguard, the interior retrenchment with its wall *df*, and the tower, which will compel the enemy to make four successive breaches before opening a passage. They claim that the main ditch is most efficiently flanked by the 48 casemated guns of the great casemate, and that the construction of counter-batteries against this work is next to impossible. The besieger has in fact no space to erect a battery on the counterguard except near the salient close to the counterscarp; room is found there for 11 guns, of which 8 only can be directed against the casemate; these 8 guns opposed by the 48 alluded to, and by 24 more in the casemated gallery, could not fire a shot. The other advantages pointed out are that the casemated gallery will continue to defend the counterguard until it is entirely destroyed, that the defence will be very energetic from the rapidity of the communications which facilitate numerous sorties, whilst the garrison and the ammunitions are in safety under bomb-proof shelters. And lastly, that the approaches of the besieger will advance exceedingly slowly, because the great development of the counterguard will permit the defenders to employ three times as many guns as in the bastion system, and the casemates of the rear firing in capital over the counter-guard, will ricochet the zig-zags. They conclude by saying that the enemy cannot proceed any further than the covered way, and that the siege will become a blockade. On the other side, it is admitted that such would be the case *if* the casemates were intact when the enemy crowns the covered way, but it is justly argued that these casemated batteries will have suffered much from the ricochet batteries of the first and second parallel, firing over the general counterguard, and that if the defence commands more guns than in the bastion system, the attack can also bring more. The method of attack proposed against this system, consists in counter-battering the casemates from the first or second parallel by ricochet; the third parallel is constructed at the foot of the glacis, the covered way of the salients is crowned, a fourth parallel runs between them, and a breaching battery is erected opposite the middle of the face of the counterguard. The covered way before the lunette is next crowned, the parapet of the lunette is breached by a battery constructed opposite its face. Once master of the lunette, the besieger constructs a battery on the terreplein to open the wall in the re-entering angle of the counterguard, crosses the ditch by a bridge, and passing through the breached wall enters the

counterguard by the breach previously made in its face. Batteries are next erected near the re-entering angle of the counterguard to breach the casemated gallery; and if necessary, the mines will complete the destruction of the great casemate. Passing the main ditch by means of the masonry bridge, the besieger will enter the place, thus turning the inner counterguard and the interior re-trenchment.

Such an attack would be folly unless the fire of the casemates had been silenced, and it is *the* question which now divides the French and the German engineers. The latter contend that it is impossible to destroy the casemates by means of "feux courbes," and that it would require, to silence them, tenfold the time necessary to take a fortress of Cormontaingne; and as one of the chief aims of Fortification is attained, they say that this system is superior to the bastion. The former assert that the great outlay of masonry and artillery is pure loss, as the casemates can be destroyed at a distance, and all the flanking defence destroyed before it is called into play. Nothing but actual experience will end the discussion, but the recent improvements of artillery cannot turn to the advantage of the casemates.

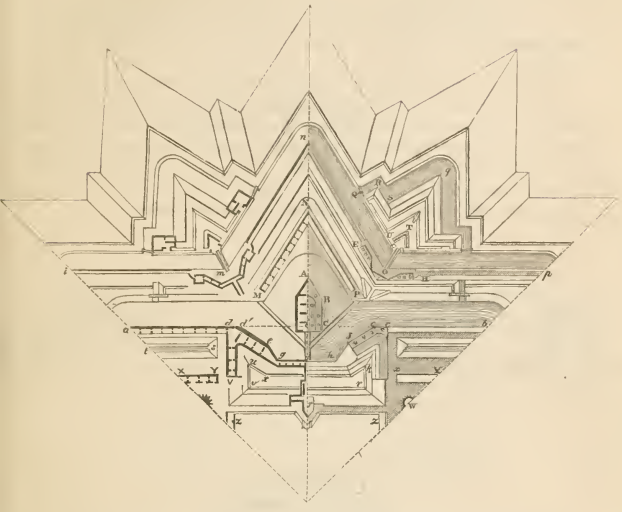
(406). *Second system.*—In 1777, Montalembert published his second system. It is called *polygonal fortification*, and this name now applies to all fortification where the faces, forming salient angles only, or re-entering angles of small depth, are flanked by a caponier constructed in the main ditch.

The following outline is proposed by Montalembert for a square, having an exterior side $a\,b$ of 370 yards. On the middle of the front the caponier is constructed by tracing its gorge about 4 yards inside the polygon, making it 14 yards wide, giving 16 yards to its flanks, and inclining the faces at 60°. This caponier, three stories high, is destined to contain 27 casemated guns on each flank, besides a numerous infantry. At 30 yards in rear, and parallel to the front, draw the curtain $g\,h$, and make it 64 yards long: from the middle of the front take the distances $i\,c = i\,d = 83$ yards, make $c\,c' = d\,d' = 14$ yards, and draw $d'e$, $c'f$ perpendicular to the direction of the faces of the caponier: joining $e\,g$ and $f\,h$, the enceinte $a\,d\,d'\,e\,g\,h\,f\,c'\,c\,b$ is obtained. When the front to be fortified increases in length, the construction remains the same, so that the parts $a\,d$ and $c\,b$ are the only ones that become longer.

The main ditch, 25 yards wide, surrounds the caponier and the enceinte: in front of it stands the general counterguard, which is 36 yards thick, except before the faces of the caponier, where the thickness is increased to 50 yards, to give room for a defensive barrack M N P, loopholed for infantry, and two stories high. A casemated battery E H, two stories high, with a curtain of 18 yards, flanks of 20, and faces of 12 yards, is constructed in each re-entering angle to flank the ditch of the counterguard 15 yards wide. A lunette of 65 yards of

gorge, with flanks and reduit, is traced as in the first system. A covered way also surrounds the whole.

Fig. 761.



The enceinte from b to c, and from a to d, consists of a casemated gallery similar to that of the tenaille system: the casemates $c\,c'\,f$, $d\,d'\,e$ three stories high defend the ditch of the caponier, this is 12 yards thick: the parts $f\,h$, $e\,g$, called "retired flanks," are constructed like the casemated gallery, and defend the ditch in rear of the caponier. The curtain has, besides the gallery and above it, a loopholed wall 6 feet high serving as parapet. A casemated battery of three stories connected with the battery $d\,d'\,e$, has a length $d\,v = 55$ yards, and a thickness of 8 yards.

In rear of the curtain stands a cavalier, the crest of which $v\,u\,x\,y\,k\,r$ is parallel to the curtain, and at 15 yards from it, and from the casemate: the crest $v\,r$ is at 16 yards from $x\,y$. The base of its exterior slope towards the place is surrounded by a small ditch, 8 yards wide, the escarp of which is 25 yards from the extremity V of the casemate.

At the salients of the front we find an inner counterguard 25 yards thick, having its gorge at 37 yards from the enceinte; 14 yards in rear of this gorge stands a casemated barrack X Y; a similar barrack z is traced in the prolongation of the face d V, and the centre of the space intervening between the two barracks is occupied by a tower. The inner counterguard is flanked by the casemate d V, and the small ditch in rear of the cavalier by the small caponier p.

As for the communications, ramps lead from the place to the ditch at the foot of the cavalier, from which the counterguard, barracks and tower are easily reached. A postern leads from caponier F, under the cavalier to the middle of the curtain: there a bridge leads to the caponier, and two others to the re-entering angle of the gorge of the counterguard. The rest of the communications remain the same as in the first system.

In the following profiles, $x\,x$ represents the level of the country.

Fig. 762.

Fig. 763.

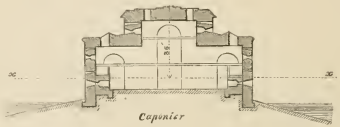


Fig 764.

Fig. 765.

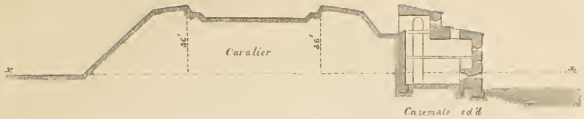


Fig. 766.

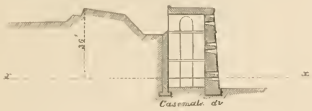


Fig. 767.

Fig. 768.

Fig. 769.

(407). The advantages claimed for the polygonal fortification in general are that it is simple and allows of more unity and ensemble to the defence; that it is economical, because for a given perimeter it encloses a larger space than any other tracing; that the defence, being derived from the middle of the front, the front may be extended to 600 yards without making the lines of defence greater than 300 yards; that the enemy will thereby be compelled to execute an immense development of trenches; and that the fronts may be armed with an artillery

far more numerous than the bastion system. The defence of the ditch is secured by a sweeping fire; and canister may be advantageously used, whilst it is too dangerous for the garrison itself, when the guns of the flanks of bastions attempt to employ it. There being no longer dead ditches, the fronts may be made as small as the irregularities of the ground may require.

(408). It will readily be seen by the inspection of the profiles that in this system in particular the third stories of the caponier, of the casemates d V, d e, of the flanks $e\,g$, $f\,h$, of the curtain and of the barracks X Y and z, have a command over the counterguards, and overlook the ground of the approaches. They are intended to oppose the opening of the first parallel, and to destroy the ricochet batteries enfilading the covered way, the counterguard, and the cavalier. It is true that these batteries would soon be destroyed, since the besieger attacking the salient of the square would be exposed to 230 guns situated in the casemated batteries of both fronts, and to 200 guns mounted on both counterguards, altogether 430 guns. But the besieger will not thus expose himself: he will counter-batter directly these high stories which are much exposed. They will soon be overthrown, and there will be no difficulty in reaching the glacis. The great caponier is badly constructed: the besieger, once master of the counterguard, can erect batteries and counter-batteries opposite the salients of the square, and take this caponier between two fires, the defenders being exposed to the projectiles entering the embrasure, both in front and rear.

We might also repeat what we have said of the effect of the ricochet fire, but setting aside the question, we can object against this system as well as against the first: the excessive accumulation of casemates; that the walls are too thin, the armament required too considerable; that the defenders, constantly under cover, dread the open air and become timid, and that the casemates present the defects already alluded to in No. 378. The other details of construction we do not name, because, in giving the systems of Montalembert, we had only in view to explain his principles.

(409). Montalembert also proposed a circular fortification.

It consists of two casemated enceintes A A, B B (fig. 770) four stories high, surrounded by a tenaille enceinte two stories high. A shallow ditch with a cunette in masonry, and a covered way with re-entering places of arms surround the whole. Caponiers for musketry m, m, flank the interval between the enceinte; p, p, are powder magazines. This fortification is not practically possible: every one can see that the high casemates of the enceinte B B are doomed to destruction at the very onset, and that the effect expected from their immense armament is but an illusion.

Fig. 770.

Fig. 771.

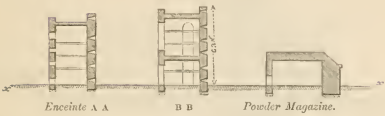


Fig. 772.

(410). Before taking leave of Montalembert we may say a word about his towers, which have been imitated by German engineers. Their base consists of tenailles having salient angles of 60°, and re-entering angles of 90°. These tenailles support arches of greater or less dimensions, according to the size of the tower, and under the middle of these vaults redans of 90° salients flank the faces of the tenailles, so that every point round the foot of the tower is seen by the defenders. With such angles, the base of the tower must contain at least twelve salients. Montalembert gives 60 feet diameter to the smallest, and 144 feet to the largest tower with twelve redans. For a greater diameter the number, or the saliency of the redans, must be increased. When the diameter = 144 feet, a second tower can be constructed inside the first, when 201 feet, there is room inside for two other towers.

Fig. 773.

Fig. 774.

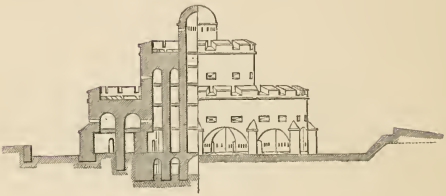
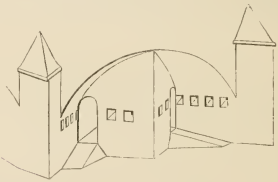


Fig. 775.



We represent here a double tower, the diameter of the larger being 144 feet. The tenailles are loopholed for musketry. Ramps lead to gates *a a* placed in the re-entering angles, and from thence through other doors *b b* to the interior of the ground floor. The exterior wall is supported by the arches of the re-entering angles: pillars rise from the foundations to the platforms, where bomb-proof

vaults connect them. The casemates *m m* of the inner tower are loopholed for musketry to defend the interior of the casemates of the large tower. The platforms of both are pierced with embrasures for artillery, and a cupola for infantry, occupies the centre of the platform of the inner tower. A winding staircase connects the casemates in each tower. Powder magazines and cisterns are placed in the cellars.

Such a tower is armed with 72 guns; and as the superior platform is 46 feet above ground, Montalembert expects that the besieger will be much delayed in the construction of his approaches, and prevented from constructing his breaching batteries. This will not, however, be the case, because the superior stories of such a tower will be destroyed from a distance.

SECTION II.—Carnot.

In 1810 Carnot proposed to base the defence of fortresses on sorties and vertical fire (486).

(411). In order to make a vigorous resistance, he recommends frequent or almost continuous sorties as soon as the enemy has constructed his third parallel, and to render them more rapid and easy, he suppresses the revetment of the counterscarp of the ditch, and replaces it by a gentle slope. As the enemy will be compelled to maintain strong covering parties in this third parallel, Carnot proposes to have at the salients of the front of attack some casemated batteries of mortars, that will pour a shower of projectiles on the crowded parallel. The besieger, he thinks, will suffer so much that he must withdraw to the second or first parallel, and cover his saps by small detachments only, in which case further sorties will have a fair chance of arresting the progress of the attack.

Carnot exaggerates the effects of vertical fire. As a 12-inch mortar throws a shell of 150lbs., he reckons that it will throw 600 shots of $\frac{1}{4}$lb. Placing two mortars at the salient of the ravelin and of the two bastions of attack, he calculates that 3600 shots will be fired simultaneously. Supposing that one shot out of 180 disables one man, he finds that every discharge will kill 20 men, or 2000 men a-day for 100 rounds. Since the besieger employs generally ten days from the third parallel to the breach, he will thus lose 20,000 men! This calculation is wrong, because it requires more than 180 shots to hit a man, and even then the momentum of a $\frac{1}{4}$lb. shot in falling is not sufficient to disable him. Hence it follows that the enemy will not be prevented from keeping a numerous guard in his third parallel: the sorties will have no longer to deal with weak detachments, and, in a word, the whole theory falls to the ground.

As his systems contain several peculiarities which have been applied to recent constructions, we shall pass them in review.

(412). First System. The side $a\,a'$ of the polygon $=370$ yards. Through the points a, a', called the centres of the bastions, draw the capitals A S, $a'\,s'$. On the middle of $a\,a'$ erect a perpendicular A $b=29$ yards, and the point B will

Fig. 776.

be the centre of the tenaille. On both sides of A measure A $c=$ A $c'=82$ yards. Through b draw the lines of defence $c\,d'$, $c'\,d$. At c and c' draw $c\,f$ and $c'f'$ perpendicular to the lines of defence, they will represent the flanks of the bastions. On the line of front, $a'\,a$, take $c\,h=c'\,h'=50$ yards: these give the revetted gorges of the bastions.

Through h and h' draw parallels to the capitals: these give the direction of the retired flanks, which are 30 yards long. The escarp $l\,l'$ of the curtain is drawn parallel to and 8 yards from $a\,a'$. The magistral of the enceinte is thus determined $d\,f\,c\,h\,l\,l'\,h'\,c'\,f'\,d'$.

The general retrenchment is parallel to the curtain. Its loopholed wall $m\,m'$, 50 yards from the escarp $l\,l'$, is limited in m and m' by the prolongation of the

retired flanks; and $m\,n = m\,n' = 25$ yards, measured on these directions, are the flanks of casemated batteries, the front walls $n\,n$, $n'\,n'$, of which are described with circles, having their centres on the capitals, and their circumference tangent in n and n' to lines parallel to the front. The crest is parallel, and 20 yards inside.

The tenaille is traced on the lines of defence, and is separated from the flanks of the bastion by a ditch 10 yards wide.

The ditch before the bastion is 12 yards wide, and its counterscarp is parallel to the faces.

The cavalier is traced with its flanks $o\,p$, $o'\,p'$, perpendicular to the faces of the tenaille, 50 yards from the centre: they are 60 yards long; the gorge is traced on the counterscarp of the ditch of bastion; the faces $p\,r$, $p'\,r$, are determined by the lines $f\,p$, $f'\,p'$, which join the shoulder angles of the bastions to the extremities $p\,p'$ of the flanks.

The counterguards $s\,t$, $s'\,t'$, 24 yards thick, are terminated at 12 yards from the flanks of the cavalier.

The ravelin, also 24 yards thick, is traced in describing an equilateral triangle on $a\,a'$: its faces terminate at 12 yards from the counterguard.

The counterguard and ravelin are surrounded by a ditch 12 yards wide, and beyond this is the countersloping glacis 50 yards wide.

A caponier or ramp leads from the terreplein of the tenaille up to that of the cavalier.

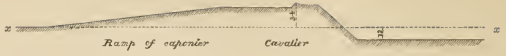
In the profile the lines $x\,x$ represent the level of the ground.

Fig. 777.

Fig. 778.

Fig. 779.

Fig. 780.



It will be seen that the bastions are surrounded by a loopholed wall masked by the counterguards: it is 24 feet high, 6 feet thick, with arched recesses on the inner side, and a chemin des rondes 6 feet wide. The gorge alone is unrevetted, to facilitate the sorties against the lodgment of the besieger.

On each wing of the curtain, along the retired flank, is a postern, which establishes the communication between the ditch of the retrenchment and that of the curtain. Another postern in the retired flank leads by a flight of steps to a little yard *h l v*, 12 yards wide, situated on the level of the ground and surrounded with a loopholed wall to give flank and reverse fire on the enemy attempting to attack the retrenchment; it contains also two guns in embrasure behind *h l* to flank the ditch of curtain.

The interior retrenchment is provided with a detached wall 36 feet high and 6 feet thick. It is 9 feet thick in the salient parts, *n n*, *n' n*. It has also arched recesses and a chemin des rondes, which communicate with the interior of the place by posterns constructed under the ramparts. In the salient parts *n n*, *n' n'*, the lower row of loopholes is destined for hand mortars, to fire at the lodgment of the bastion.

On rear of these salients stand the casemated batteries *n m y*, *n' m' y'*, composed of vaults open both in front and rear, to facilitate the egress of smoke; each vault contains 2 mortars to throw stones on the lodgment of the bastion; and the extreme piers *m n*, *m' n'*, are pierced with three embrasures for three guns flanking the ditch.

We have not represented in the plan the three batteries of mortars at the salients of ravelin and bastion, which Carnot recommends for the front attacked, nor a casemated battery of guns in the circular parapet of the retrenchment, which he intends to fire at ricochet against the zig-zags in capital, and at point blank on the lodgment of the bastion.

(413). Carnot claims for his system a great economy in the first outlay, a great durability for his walls; and as he dispenses with the covered way and its enormous palisading, and has a strong interior retrenchment ready, there will be a great diminution of the labour usually required during the siege. The defence, he thinks, will be protracted, as the high rampart commands, and plunges the approaches; the parapets independent of their scarps cannot, in falling, afford a practicable breach; the great batteries cannot be seen or destroyed either by ricochet or vertical fire; the men are well sheltered under the arched-recesses;

the counterguards offer but a narrow aim to ricochet; and the counter-sloping glacis exposes to plunging views any sap which the besieger might carry through. All these advantages, backed by the sorties and vertical fire alluded to, appear to Carnot extremely superior to those of the modern front. It is not, however, the case. The detached walls are excellent to prevent the escalade, but they may be breached at a distance by vertical fire, so that the ramparts of earth behind them can be ascended. Supposing that the besieger proceeds with regular attacks, we have already said that, after the construction of the third parallel, he will not be compelled to withdraw on account of the vertical shower of projectiles; and, as for the sorties, he can construct batteries at the salients of the glacis to breach the faces of the bastion and the flanks of the cavalier, and at the same time spare a gun or two to fire grape shot into the narrow ditches from which the sorties must debouch. A fourth parallel, connecting the crowning of the glacis, will render the sorties still more difficult, especially if these batteries have been surrounded at night by chevaux-de-frise, trous-de-loup, &c., that delay the garrison and give time to the guard of the fourth parallel to come up.

The ravelin does not seem necessary: it obliges the enemy to commence his approaches at a greater distance, and covers partly the debouché through which the sorties must pass, but it may easily be breached by live shells or mining, and as it is unrevetted both in front and rear, and contains only a feeble garrison, it may be stormed in all directions. The cavalier, one of the chief features of the system, masks the fire of the collateral bastions, and as it is unrevetted, it may be assaulted at the gorge. Once master of the cavalier and tenaille, the besieger can employ the mine against the counterguard without being molested, and make a wide opening through it: a battery constructed opposite that point in the crowning of the glacis will breach the bastion. In the bastion the enemy finds space to construct a battery against the casemate: he may suffer from the fire of the mortars and pierriers, but he can employ blind frames; and as he has room to place a superior artillery, the casemate is too small to resist long: the battery in the circular rampart will not resist long for the same cause.

This system does not, therefore, bear investigation: nevertheless, the detached walls, the counter-sloping glacis, and the casemated mortar batteries, have found numerous advocates, and are frequently employed. It is but just to add, that these casemates have been borrowed from a work published in 1781, by Virgin, a Swedish engineer.

(414). Second and Third Systems. The first system of Carnot was intended for a flat country, where water is not found above 12 feet in depth. The second is destined for a marshy country, where excavations cannot afford great remblais. It is the tenaille outline of Montalembert. The interior retrenchment consists of a loopholed wall $a\,b\,a'$, the salients $a\,a'$ of which are 200 yards apart. It has no

FIG. 781.

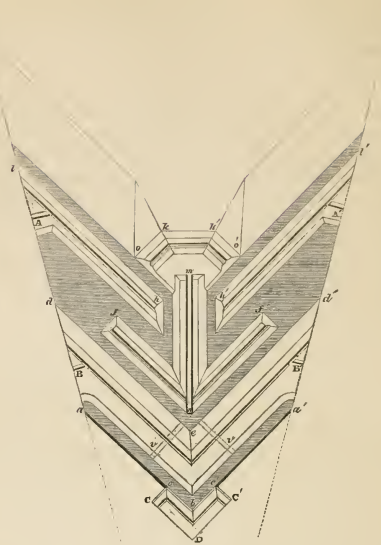


FIG. 782.

rampart behind, and is provided with two stories of arched-recesses. The ditch that surrounds it is 12 yards wide. At the re-entering angle is a casemated battery C C′, in which C D = C′ D = 48 yards. The front walls *b c*, *b c′* are pierced with five embrasures for the defence of the ditch; and the platform is organised for 16 guns. The enceinte *d e d′*, 40 yards thick, has no revetment; it contains traverses B, B′, 12 feet thick, near the salient, behind which a few mortars may be placed: the vaulted passages *v v* serve to place the boats under shelter. The tenaille, 25 yards thick, is surrounded on both sides by a ditch

12 yards wide, and has wings 120 yards long, measured on the gorge, to cover the enceinte behind the extremities of the counterguards. These have the same thickness as the tenaille, and are preceded by a ditch of 12 yards and a counter-sloping glacis of 50 yards. A double caponier 36 yards thick, with a passage *m m* 8 yards wide, connects the tenaille with the place of arms $o\,k\,k'\,o'$: this is serviceable during the sorties. There is a ditch of 8 yards width between the counterguards and the caponier: the traverses A A′ are similar to B, B′. The flanks $o\,k$, $o'\,k'$ of the place of arms $=40$ yards, the faces $k\,k'=50$ yards.

In the third system, intended for mountainous countries, the ditches are dry. The interior retrenchment is the same as in the second system. The enceinte is protected from escalade by a detached wall 18 feet high: it contains several posterns for the communications. In the re-entering angle there is a little yard *y*,

Fig. 783.

Fig. 784.

Fig. 785.

the faces of which flank the ditch with three guns. The tenaille is surrounded

in front and gorge by a wall of 18 feet. The counterguard, caponier, place of arms, glacis, &c., are the same as before.

Very little need be added. With wet ditches, the sorties made from the place of arms cannot be so numerous as Carnot requires them, and they debouch from a point much exposed to the batteries of the besieger. The place of arms, which is not palisaded, is exposed to be stormed. The caponier and the long wings of the tenaille mask the fire of the enceinte, and the ditch has but a weak flank defence.

CHAPTER XXV.

GERMAN FORTIFICATION.

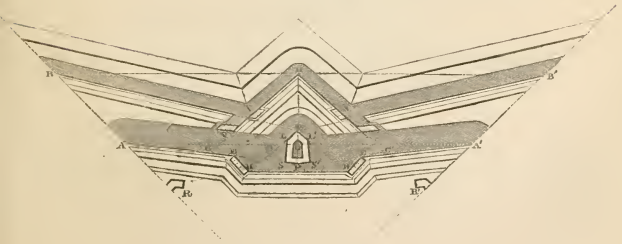
SECTION I.—German System.

The engineers of Germany, Prussia, and Austria, have adopted several of the ideas of Montalembert and Carnot, such as the polygonal tracing, the caponiers, the casemated batteries, the detached walls, and the countersloping glacis. All the fortresses they have built since 1815 present common features, and the name of *German* System has been given to the ensemble of their disposition. It should however be understood, that the merit of these innovations is not universally acknowledged on the right bank of the Rhine. Some engineers in fact object to the countersloping glacis, others to the detached walls, and some reject both.

(415). The fortifications of Coblentz may be selected as a type of the new method. The annexed tracing (fig. 787) is that of a front of Fort Alexander

Fig. 786.

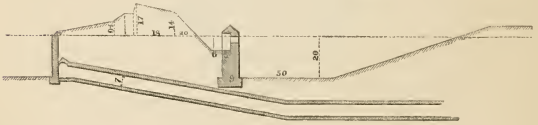
Fig. 787.



(fig. 786) according to the Sandhurst course. The exterior side A A′ = 510 yards: bisect it in O, take the perpendicular O P = $\frac{1}{6}$ of the side, and draw the line of defence P A, P A′. The counterscarp of the main ditch is parallel to the lines of defence, and at a distance of 30 yards from it. The ravelin is obtained by bisecting the lines of defence in C C′, taking P D = P C = P C′, and joining D C, D C′. The ditch is 18 yards wide. The demigorge P S, P S′ of the caponier = 18 yards: the flanks L S, L′ S′ are perpendicular to the lines of defence, and are terminated at the counterscarp of the main ditch; the faces T L and T L′ are next drawn parallel to those of the ravelin. The counterscarp of the ditch in front is 30 yards from the faces. The top of this counterscarp produced intersects the lines of defence at E E′, and the flanks E H, E′ H′ of the enceinte are traced perpendicularly to the prolongation of the faces of the caponier. A parallel to the side A A′ drawn through the salient D of the ravelin, will give in B and B′ the salients of the counterguards, the faces of which are directed to the salient angle T of the caponier. The ditch in front of them is 18 yards wide. The covered way is replaced by a countersloping glacis 20 yards wide, and a glacis of variable width. The profiles give the command of the various parts.

Fig. 788.

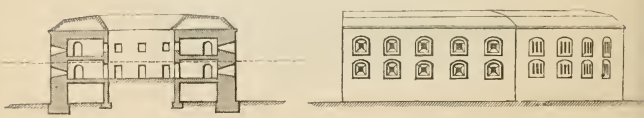
Enceinte.



Counterguard.

The caponier destined to defend the ditch contains two stories of casemates; each flank thus mounts 10 guns; the faces are loopholed for musketry. This

Fig. 789.



Caponier.

outwork will hold a garrison of 160 men. Each of the flanks E H, E' H', con-

Fig. 790.

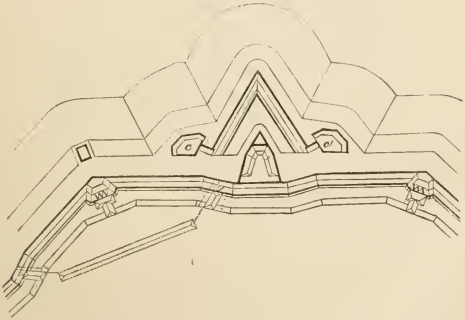
tains six casemates for guns. The ditches of the ravelins are defended by casemated traverses Q Q', which protect the enceinte in rear. The ditches of the counterguard are defended by casemated batteries X, X'. The casemated batteries for mortars are placed at the salients of the polygon in R and R'.

(416). At Gemersheim the caponier contains either one or two stories of case-

Fig. 791.

mates for artillery; at the salient a little triangular space is left open, and gives room for a mortar to throw shells on the approaches. The tracing differs but little from that of Coblentz. The ditch of the ravelin is also defended by case-

Fig. 792.



mates, and there, as well as in some of the fronts at Coblentz, the re-entering angles are occupied by casemated redoubts, C, C'. Reduits are also formed in

the salients of the covered way. Gemersheim presents however this difference, that the revetments are counterarched and loopholed for musketry. The casemated mortar batteries are replaced by a pentagonal area left at the salients of the bastions behind the revetment; the escarp gallery leaves the wall so as to form a courtyard 20 yards by 7, in which five casemates for mortars open. They communicate with the interior of the place by a postern, and are surrounded by a

Fig. 793.

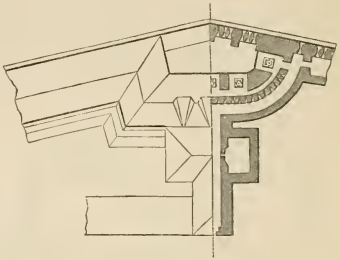
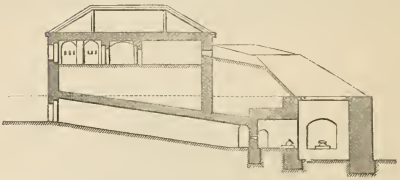


Fig. 794.



loopholed gallery. Right and left of the postern are two powder magazines, the walls of which rise above the rampart and form a hollow traverse, which protects the faces of the bastion against ricochet, whilst in the interior there is room for a battery of three guns. These traverses have a command of 6 feet over the adjoining parapets.

Similar traverses are also constructed near the shoulder-angles, and are preceded by a ditch forming a coupure. A defensive barrack at the gorge is connected with these coupures, or a retrenchment is constructed for the purpose of ulterior defence. In the plan we have traced a countersloping glacis, but at Gemersheim the place is surrounded by a covered way with a revetted counterscarp, as represented in the profile.

Fig. 795.

(417). At Ingoldstadt the caponiers are detached, and form a kind of citadel: troops can thus make their exit from the place with rapidity, whilst re-entering

Fig. 796.

places of arms in the covered way further facilitate the sorties. We find these casemated batteries for the defence of the ditches of ravelins or counterguards, and hollow traverses at the salient of these outworks to resist ricochet and contain heavy guns to fire on the approaches.

What precedes will give a fair idea of the manner in which the principles of Montalembert and Carnot have been applied in the recent constructions of Germany, and instead of entering into further descriptions, we think it more useful to discuss their leading features.

(418). The partisans of the bastion tracing have criticised the German system in the following manner:—The great opening of the angles of the polygonal fortification permits, more readily than with the bastion tracing, the long faces to be directed to those points of the ground on which the enemy will find it difficult to erect his batteries, and in the most recent constructions, as at Radstadt, (423), the caponier is brought forward so as to increase the opening of the angles formed by the faces; the ricochet is thereby rendered more difficult. This disposition, together with a greater extent of the fronts, will necessitate a greater

development of the first and second parallel, but this is not an obstacle likely to delay the progress of the attacks. The besieger will as usual construct his batteries to ricochet the faces of the ravelin, of the counterguards and the enceinte, and will even erect in his second parallel a counter-battery to fire across the ditch against the caponier, which a pitching fire of heavy guns can easily reach. The hollow traverses constructed on the ramparts are armed with too few guns to hold out long, their masonry must soon give way, but their remblai will continue to form a good protection against ricochet, not such, however, as to hinder it entirely. The besieger will reach the foot of the glacis, and make his third parallel as in ordinary circumstances. Having arrived there, his further advance is no longer checked by the grazing fire of the covered way; that of the outworks is more plunging and distant, and if the sap can progress before a covered way, it will certainly progress no less rapidly before a countersloping glacis, especially since trench cavaliers can be dispensed with. The defence relies upon the sorties which can be made with considerable force, but the besieger is aware of it, and as he is superior in number and protected by a parallel, there is every reason to suppose that the engagement will turn to his advantage; in that case he can pursue the defenders to the very gates of the place, and very speedily return to his parallel, whereas he could not follow up his advantage if there were a covered way. At night he may enter the ditch, and watch the preparations made for these sorties. As for the small sorties against the heads of the sap, they will be less practicable also; and unless the ditch be permanently occupied by detachments, which it cannot be, they must be less frequent; when retreating they have upwards of 250 yards to run over under no protection, since the casemates in the ditch cannot fire on both friend and foe; and when the enceinte is re-inforced by counterguards, the retreat will be dangerous; the defenders must pass through the narrow defiles at the extremities of the counterguards which the enemy may occupy, whilst the sortie struggles with the sap, because he is nearer those defiles in some parts of his third parallel: the retreat may thus be cut off. The counterguard once lost, these defiles are easily observed, and future sorties become next to impossible. This is not all, for the harm done to the sap will be more rapidly repaired on account of the musketry fire being less troublesome. The sorties would altogether prove too precarious a means of defence. Moreover, the advocates of this system expect much from the casemated mortar batteries: these will certainly continue firing on the approaches; now this has always been the case in former sieges, because the mortars may be placed anywhere, and the defender invariably places them on the points least exposed to ricochet. There is no reason why they would do more harm than in the bastion system; and the besieger will reach the crest of the glacis very likely sooner than usual, because the little saliency of the outworks will permit him to crown simul-

taneously the glacis of the ravelin and of the counterguards or bastions. To prevent the crowning, the loopholed wall and the casemated batteries are not properly organised; the loopholes, as may be seen by an inspection of the profiles, are only 10 feet above the bottom of the ditch, and much below the crest of the glacis; their fire will therefore be too ascending to prove a serious impediment; the same may be said of the caponiers having but one story. At Coblentz the superior story commands a good view of the crowning; but its artillery can no more prevent the crowning than that of the bastion system, and perhaps it is even less effective for this purpose, as we shall see presently. The little reduits, erected in the salients of the counterscarp, and destined both to secure access to the galleries of mine and to give reverse fire in the ditches, could not either arrest the crowning, because their front wall is not flanked, and the besieger can fill their small ditch with fascines or sandbags and destroy them by mines. There is thus good ground to suppose that the glacis will be crowned by the besieger, and this done, the work of the attack becomes simplified.

Engineers who object to the polygonal fortification, are of opinion that the ulterior defence will be very slack, because the flanking defences will have been ruined by this time. The caponiers and detached walls, as well as the traverses and reduits in the ditch, are in fact as much exposed to the pitching fire of the batteries of the second parallel, as if there were no glacis or counterguard before them. They base their opinion upon the experiments made at Woolwich, in 1822 and 1824, when a Carnot wall protected by a counterguard, was breached by a battery of eight 68-pounders at 500 yards, and a battery of three 8-inch, and three 10-inch howitzers, at 400 yards. By firing at an elevation of 15° with solid shot, and shells full of powder, a practicable breach was made in six hours by 100 rounds from each piece. Next day, 50 rounds rendered the breach perfectly practicable, and on the third day of the experiment the wall was a mass of ruins. It must be said that the firing was rectified, as the effect of each shot was observed and the elevation or charge altered, in actual warfare such could not be the case; but the possibility of destroying walls at a distance by pitching fire is more or less an established fact; and with a greater or less number of rounds, the walls of the caponiers, &c., must be ultimately destroyed, or at least suffer heavily. Without going so far, we shall suppose that these walls have not been so much injured, and see how the besieger would proceed after having crowned the glacis. He will construct counter-batteries against the casemates defending the ditch. Montalembert declared that it would be impossible to do so; but we do not find in German fortresses that immense superiority of artillery which he proposed; the artillery may do harm and somewhat delay the completion of these counter-batteries, but the experience of past sieges proves that the flanks of bastions left intact, and even re-inforced by retired flanks, could not prevent the construction of these batteries.

and the caponiers or casemates even un-injured, do not bring much more to bear on the crowning. Should there be no counterguard, the question of "earth *versus* masonry," will soon be settled, the caponier must be silenced as it presents too wide a surface, and every shot does it too much harm to admit of a long resistance. The ditches are then dead, and before giving the assault there remains only the detached wall to breach, which the counter-batteries themselves can do. If, as at Gemersheim, the enceinte has a regular revetment, the besieger will have no difficulty in destroying the front wall of the pentagonal area, since it is too weak; the loopholed wall in rear would not resist long either, and a lodgment would thus be easily obtained, from which the miner could blow up the enceinte, and make a regular breach, or breaching batteries might be constructed against the faces. The ravelins, if they had not been abandoned, and the enceinte, could be stormed simultaneously as early as the 15th day of the siege. If the fronts are re-inforced by counterguards, the counter-batteries of the salient of the glacis, will have to destroy first the casemated batteries or redoubts flanking the ditches of ravelin and counterguard, if this has not been done by the batteries of the second parallel, and also to breach them at their extremities. The lodgments may be made here, as before, without difficulty, since there is no descent of the ditch required, a sap being quite sufficient, and the long ditches, now dead, serve the besieger for the depots, &c. A lodgment on the exterior slope at the salient of the counterguard, can be transformed into a counter-battery sufficiently strong to overpower the caponier, and to breach the enceinte as before; or a trench may be run across the terreplein of ravelin for a battery that will breach the curtain; but the besieger need not do so, as he might be exposed to the casemates that defend the ditch of the caponier; by breaching the enceinte on the faces, these batteries might be turned and rendered useless, and so much so, that at Gemersheim they have not been constructed, but replaced by three embrasures at a small height above the bottom of the ditch.

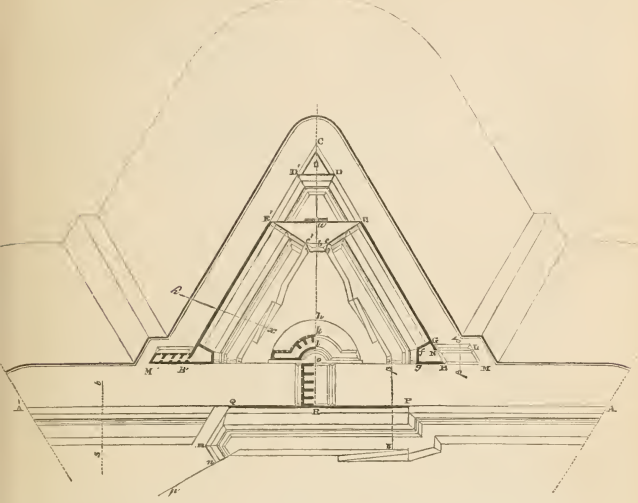
After breaching the enceinte, the enemy is entirely master of the ditches, and cannot be disturbed, he will be at liberty to turn the interior retrenchment by the mine, or construct in his lodgment on the exterior slope of the enceinte, where he is altogether unseen, some batteries to destroy the defensive barracks, and give the final assault on the 20th day.

(419). The name of *Prussian system*, is now given to a polygonal tracing possessing a decided superiority over the tracing of Fort Alexander. We adopt the same dimensions as are given in military schools.

The line of front A A′ = 450 yards; the main ditch is 30 yards wide, and its counterscarp is parallel to the enceinte. The ravelin is traced by taking O B = O B′ = 100 yards, and describing an equilateral triangle B C B′: its ditch is 20 yards wide. Casemated batteries for four guns flank that ditch; they are traced

by producing the gorge of ravelin, and taking B M = 30 yards, and drawing L M = 20 yards parallel to the faces; the ditch is only 10 yards wide round them,

Fig. 797.



and in front where the depth is 5 yards, it is deepened a few feet. A revetted counterscarp and a glacis 100 yards wide surround the whole front.

The ravelin is divided into three parts. The first C D D′, in which C D = C D′ = 26 yards, is a loopholed wall, and in the terreplein which it encloses, is the entrance to the galleries of countermines. The second is limited by the wall E E′, erected at distances C E = C E′ = 70 yards from the salient. The command of the parapet is greater than in the third part of the ravelin in order to protect it from enfilade, and under the parapet D D′, on a level with the terreplein of the salient is a battery for 3 mortars. In the third part, there is in front a bastion retrenchment, with perpendicular $a\,b = 20$ yards, and faces E c = E′ d' = 30 yards, an earthen parapet following the faces of the ravelin and of the bastioned front. A chemin des rondes with loopholed wall E G, gives a fire of musketry in the ditch,

it is entered by a vaulted passage under the parapet C E, and flanked by the wall of the yard G f g B. This yard is traced by taking g B and B G = 20 yards, and erecting the perpendiculars $g f$, G f: it communicates with the casemated battery and the terreplein of the ravelin. The reduit of ravelin consists of a semi-circular casemate for two stories of guns, sweeping the whole terreplein and protected from distant view by the parapet of the ravelin. It is traced with a radius O K = 22 yards, and a radius O Z = 10 yards: a ditch 10 yards wide surrounds it in front and rear, and two ramps 3 yards wide lead from the ditch in rear to the terreplein of the ravelin.

The great caponier occupies the whole breadth of the main ditch; it is 20 yards wide, and contains two tiers of 5 guns on each face: for the casemated batteries the ditch is made deeper along the front wall; and the roof of the casemate is covered with 8 feet of earth, and communicates with the place by means of a postern.

The enceinte consists of a solid revetment with parapet and rampart, but the central part, from R to P and Q, (R P = R Q = 70 yards) has a chemin des rondes and loopholed wall.

Coupures are also made: on the left of the front there is a coupure made by drawing Q m = 35 yards inclined at 122° on Q P, the flank m n of 15 yards inclined at 118° on m Q, and the curtain n p at right angles to the flank.

(420.) The advocates of the Prussian system, claim for it the advantages attributed to polygonal fortification in general (407), besides several others. The great saliency of the ravelin prevents the besieger from taking the prolongation of the fronts which are thus less liable to enfilade. The casemated batteries at the extremities of the faces of the ravelin, prevent a breach being made in the enceinte from the glacis through the ditch of that work. The parapet of the second part, protects the faces from enfilade; and the circular reduit will render the construction of breaching batteries on the salient very difficult. The communications are safe; the glacis is powerfully flanked, both by the enceinte and the ravelin; the simplicity of the whole system renders it economical; and its defence may be entrusted to a comparatively small garrison.

There is no doubt of the superiority of this tracing compared with that of Fort Alexander; and this ravelin is an excellent work, capable of a protracted defence. The salient itself is, as in the bastions of Gemersheim, a weak point, and the absence of a covered way is a great drawback.

The discussion between the advocates of the polygonal and those of the bastioned tracings can only be ended by the actual siege of one of the new fortresses. The experience of past sieges, together with the improvements in the destructive power of artillery on masonry, tend to show that the applications of the system of Montalembert and Carnot do not possess the degree of strength attributed to them.

Fig. 799.

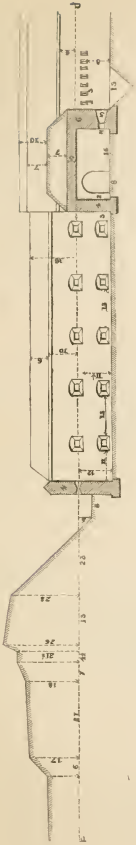


Fig. 800.

Fig. 801.

There is a great probability that the counter-sloping glacis compromises the exterior defence, and that the casemated caponiers are often liable to be destroyed from the onset. Taking even the Prussian system as a type, the advocates of the bastion tracing will oppose to it the front of Choumara, and actual experience is on their side.

SECTION II.—German Fortresses.

(421). In Austria innovations have not been as considerable as in Prussia or Bavaria. At Verona, for instance, the place is surrounded by detached works, and the enceinte seems merely designed to secure the garrison against a "coup-de-main." It consists of a mere enceinte on the bastion tracing: the fronts are 500 yards long, the curtains 300, the faces 80, and the flanks 40. The profile of curtain is the same as that of the French school, but the flanks and bastions are surrounded by a chemin des rondes, and by a detached wall forming an orillon,

Fig. 802.

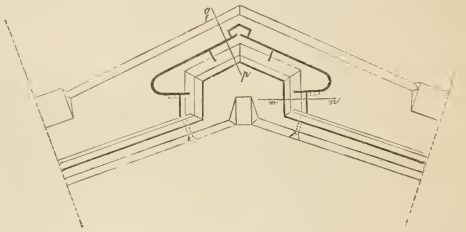
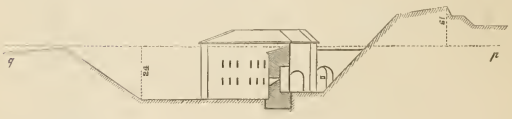
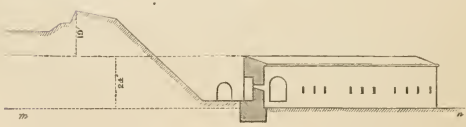


Fig. 803.



Bastionet.

Fig. 804.



Flank. *Orillon.*

which projects 25 yards on the front. Transversal walls on the faces and the flanks intersect the chemin des rondes to prevent the enemy from spreading along it, to obviate the enfilade, and by means of their gates to take in flank the storming columns.

The orillons afford space for the collection of the troops destined to make a sortie; and a gate placed along their gorge, gives access to the ditch.

A little bastionet occupies the salient; it is casemated to two stories for musketry, and flanks the ditch before the faces of the bastions.

The detached wall has arched recesses, with loopholes, the openings of which are 6 feet above the bottom of the ditch: two of the recesses near the flank are pierced with embrasures for artillery. The ditch is 20 yards wide. There is no outwork, no covered way, and the counterscarp is not revetted: on the middle of each curtain is a counter-sloping glacis.

It may be repeated here that the detached wall can be destroyed at a distance by pitching fire at the very beginning of the siege. The ditches are, however, still defended by the rampart of the flanks, and even by the bastionet. The absence of outworks, and, therefore, of crossed musketry fire, will enable the enemy to advance his saps most rapidly: nothing will arrest the crowning of the crest of the glacis except the flanks, which are 400 yards distant. As for the loopholes, they are too low, if still standing, to do harm.

Sorties are still less possible than in the polygonal Fortification of Coblentz; they must, in fact, pass over the counter-sloping glacis, and be exposed during their march on the heads of the saps in the capital to the fire of the parallel. The small re-entering angle, formed by the glacis in the middle of each front, will permit the besieger to crown the whole of it, to dispense with traverses, and to construct breaching batteries even against the middle of the curtain.

(422). The same reasons which have induced Vauban and his successors to surround fortresses with intrenched camps, have decided the German engineers to surround their places with detached works, the tracings of which differ from those of the French school erected at Paris and Lyons. Fort Alexander, at Coblentz, is a detached work, but its outline is by no means generally adopted. The detached forts round Cologne will give a better idea of their principles (fig. 805).

They consist of lunettes, having faces and flanks 60 yards long; their command is great, and the flanks are covered from ricochet by hollow traverses, casemated for one gun, situated near the shoulder angles. They have a command of 6 feet over the parapet, and occupy the whole width of the rampart: a vaulted passage under them permits free circulation. At the salient is a small cavalier, having a command of 3 feet over the parapet, and acting as a traverse. A casemated caponier defends the ditch along the faces, and communicates by a gallery with the gallery of counterscarp, or with the branches of the mines. The ditches of the flanks are defended also by caponiers situated at their extremities.

Fig 805.

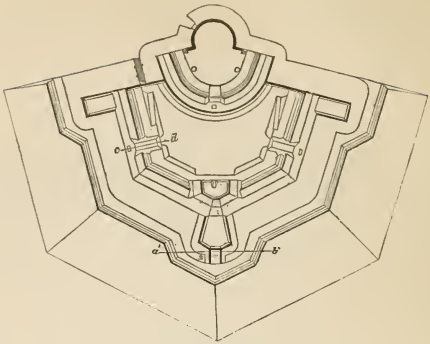


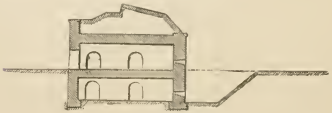
Fig. 806.

Section on the Capital.

Fig. 807.

Section on a b.

Fig 808.



Section of Redoit.

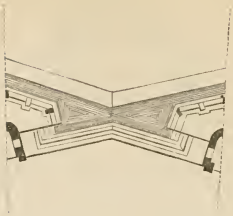
Fig. 809.

The gorge is occupied by a tower of two stories: the inferior one defends the foot with musketry: the superior, together with a platform, brings 14 guns to bear on the terreplein.

The cavaliers and hollow traverses are excellent arrangements for remedying the ricochet of the faces and flanks; but their gun is not capable of keeping up its fire against the several pieces which the enemy can converge upon it. The caponiers and traverses in the ditch are again exposed to pitching fire; and as the covered way has no traverse, and no place of arms, the besieger will find little difficulty in crowning it, and all the less from the caponier in the capital being too low to oppose it. Breaching batteries, constructed opposite the shoulder angle of that caponier, will be able to breach it without being exposed to its guns, which cannot fire with sufficient obliquity for the shot to reach them. The defences of the ditch once destroyed, the miner has a fair opportunity of blowing down the counterscarp, and of opening a breach in the face of the lunette by the mine. As it might be dangerous to advance on the terreplein against the redult, the enemy will blow up the parapet of the lunette, to form an opening through which the batteries of the covered way may counter-batter. Despite these defects, these lunettes are good works for uneven ground, where the position to be fortified is narrow, and the ricochet is not to be apprehended. The caponiers will then fulfil their purpose, and oblige the enemy to bring his guns to the covered way to silence them. The redult offers a bomb-proof building for the garrison, which, however small, can secure the fort against a coup-de-main. (See 342).

(423). Radstadt, a federal fortress recently constructed, exhibits the chief features of the German system, and deserves a few words. It consists of a bastioned enceinte, strengthened by three forts of different outlines, and by detached redoubts. By a judicious disposition, the three parts of which the enceinte is formed, *oberer*, *mittlerer*, *unterer*, and the three forts, form each an independent work. The bastions are wide, with orillons and double retired flanks; the curtain is broken outwards, and a casemated traverse occupies its salient. A loopholed wall, at 30 feet from the rampart, separates the town from the enceinte, in order to enable the garrison to continue its defence, should the

Fig. 810.

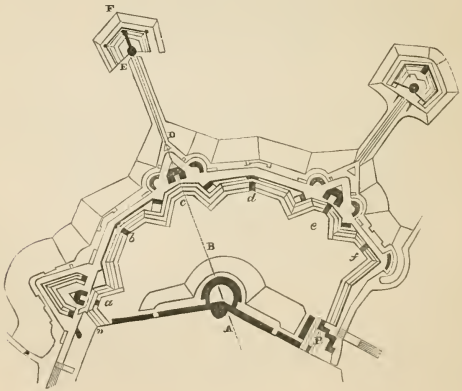


enemy enter the place at one point. The centre of each bastion is occupied by a casemated tower serving as keep, and connected by a loopholed wall with the orillons: this tower is also connected by flank-walls to a defensive barrack, which flanks the interior wall of the enceinte, their ensemble forming the retrenchment of the bastion. Traverses erected along the faces prevent the ricochet.

The ditches, 25 yards wide, are wet, and are preceded by a glacis.

The *mittlerer* and *oberer* parts of the enceinte are separated by Fort Leopold. This work consists of six irregular bastions powerfully flanking one another:

Fig. 811.

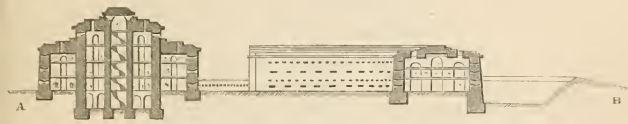


three caponiers, one of which is protected by a ravelin, defend the ditches, and are themselves supported by the flanks of the collateral bastions and their low batteries. A fausse-braye surrounds the bastions *b* and *d*, and casemated batteries stand on the salients *b*, *c*, *d*, *e*.

Fig. 812.

Fig. 813.

Fig. 814.



A covered way surrounds the fort, and the places of arms have casemated keeps of the form of a horse-shoe, which flank the covered way and glacis. The gorge of the fort is occupied by a great casemated keep with tower and defensive barracks, the masonry of which is protected by a glacis. At 300 yards from the glacis of the fort and connected thereto by caponiers, are two lunettes, closed at the gorge by a loopholed wall, with casemated howitzer-batteries in salient, and Montalembert towers for keeps. In one of these lunettes the keep and battery communicate by a vaulted passage, and the ditch is defended by small bastionets.

The fort is separated from the *oberer* enceinte by a dry ditch *n*, and from the *mittlerer* by another ditch, also 20 yards wide, on the bridge of which passes the road of Kehl, defended by a casemated battery *p*.

The second fort, between the *unterer* and *oberer*, resembles the tracing of Fort Alexander, but is better, because the flanks are double and the curtain is replaced

Fig. 815.

by a truncated bastion, whose flanks contribute to the defence of the ditch. The casemated reduits, the covered way, gorge, &c., resemble those of Fort Leopold.

The third fort, between *unterer* and *mittlerer*, is the best tracing, because the besieger would have to undergo four periods of breaching batteries and to pass two wet ditches. It is formed of a double bastioned enceinte: the outer one consists

Fig. 816.

of two bastions with orillons and double retired flanks, and a broken curtain with a cavalier at the salient. The parapet of this curtain is indented in order to defend the ditch along the flanks. Semi-circular casemated keeps occupy the centre of each bastion. The inner enceinte, separated from the first by a dry ditch, is formed of two faces defended by the semi-circular keeps. The gorge is closed by a loopholed wall and two casemated reduits. In front of the outer enceinte, are a wet ditch, then a covered way with glacis, a second wet ditch, and an advanced covered way with glacis. In the advanced ditch stand two unrevetted lunettes, closed at the gorge by a loopholed wall with Montalembert towers. The fort can be isolated from the enceinte by a system of sluices connecting the ditches with the Murg river.

The outline of Radstadt is therefore very irregular, and presents several judicious arrangements bearing on the details, but we find a great profusion of interior retrenchments and casemated keeps, which are liable to suffer seriously from the besieger's artillery before they are called into play. A system of inundations and countermines strengthens the defence; but as far as the fortifications themselves are concerned, it may be said that there is no salient capable of taking the besieger in reverse, and the enemy will advance rapidly during the first period of the siege. As for the interior loopholed wall, it would prove but a poor protection for the garrison.

(424). Ulm is a federal fortress, entirely of the polygonal tracing, with detached forts forming a retrenched camp for an army of 100,000 men.

It consists of a continuous enceinte with 12 forts on the left bank of the Danube, and of a tete de pont with 6 forts on the right bank. The enceinte on the east side is polygonal, with escarp, ditch, revetted counterscarp, and covered

Fig. 817.

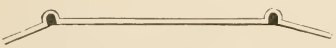
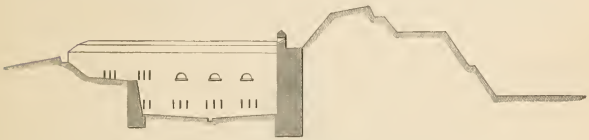


Fig. 818.



way; on the west it is traced en cremaillère, and has no ditch. The escarps are semi-detached, and the casemated reduits are less exposed than is generally the case; yet the value of Ulm is not so much due to the place itself as to its vast retrenched camp.

The caponiers differ from those of Coblentz, Gemersheim, Radstadt, &c. In that of the tete de pont, here represented, the flanks are parallel and the head is

Fig 819.

circular: the roof is bomb-proof; the walls of flanks are pierced with four or five embrasures for guns, while the circular parts are loopholed for musketry.

A disposition, found also in Fort Leopold at Radstadt, consists in the formation of two enceintes, which therefore present a double line of fire on the middle of the curtain and before the re-entering angles: the foot of the semi-detached

Fig. 820.

escarp is separated by a passage of 20 yards from a loopholed Carnot wall, entirely isolated and resting on the gorge of the caponier. This wall is pierced with embrasures for guns to flank that caponier.

(425). Mayence is a federal fortress of great importance, in which we find some applications of the German principles. It consists of a bastioned enceinte, part of which is rather old; but its southern and south-western portions, between the Rhine and the Zeil, have been carefully re-organized, and out of no fewer than eighty-eight works, sixteen have been constructed since 1806. The fort Heiligen-Kreutz, which we select for investigation, is a lunette. The escarp is

Fig. 821.

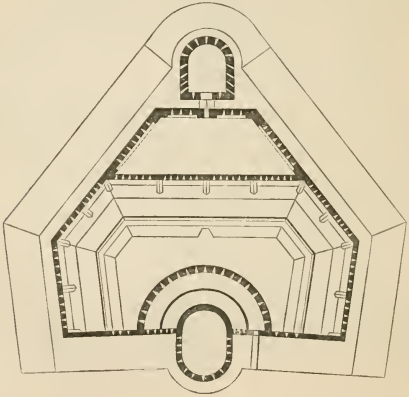


Fig. 822.

semi-detached, and the chemin des rondes is intersected by casemated traverses. The parapet forms at the salient a large pan-coupé, from which one can descend by a postern into a low terreplein, separated right and left from the ditch by the prolongation of the loopholed walls of the faces. This loopholed wall is vaulted on $\frac{2}{3}$ of its thickness. From this advanced terreplein, forming a reduit, one enters a masonry caponier leading to a casemated battery, in form of a horse-shoe, that flanks the ditches of the lunette and the salient of the glacis. The gorge is closed by a circular casemated keep, and the ditch of this gorge is defended by a caponier. It will readily be seen that this fort is inferior to those of Cologne: the ditches of the faces are obliquely flanked, and the faces and flanks are not protected by the masks resting on the gorge as in the above works.

(426). Lintz, built on the right bank of the Danube, has been surrounded by an intrenched camp, destined to give an army defeated on the Upper Danube, a safe position on both sides of the river. It is a very important strategical point, the first that covers Austria; and its bridge is the chief debouché of Bohemia. The fortifications consist of 32 towers, called Maximilian towers, from the name of Archduke Maximilian who invented them, erected nearly one mile from Lintz (the nearest, No. 21, at 1200, the furthest, No. 1, at 3200 yards), and from 500 to 600 yards apart. They are to be connected at the moment of need by a curtain, a ditch, and a palisaded covered way, the whole being flanked by the towers. It may be doubted whether an army would have an opportunity of erecting these fieldworks in due time, but admitting that it would, still the besieger would have only one enceinte to force on one point in order to uncover Lintz, and the danger is all the greater because the whole circumference being considerable, it would require a strong army to defend it efficiently.

These towers are circular buildings 33 feet high, with a mean thickness of wall of 6 feet 6 inches: the diameter of the base is 118 feet, and that of the top 110 feet. They are surrounded by a ditch 8 yards wide towards the exterior, and gradually becoming narrower towards the interior, where it is only 4 yards wide at the entrance gate, so that the communication can be established by means of a drawbridge. The deblais of the ditch have been employed to construct a glacis, that covers the masonry on the exterior, and gradually falls to the level of the ground in rear.

Fig. 823.

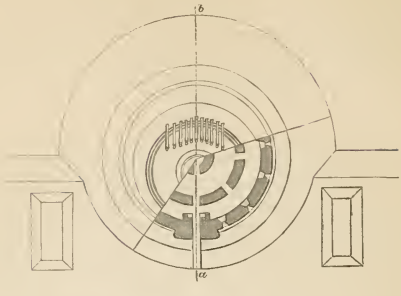


Fig. 824

The centre of each tower is occupied by a hollow cylinder, 3 yards in diameter; and the interval between its side and the scarp wall is divided into two by pillars connected by bomb-proof arches. A bomb-proof circular vault covers the whole. The tower has three floors: the lowest serves as magazines for stores, and has a covering vault bomb-proof. The second, covered by strong beams, contains the garrison and the kitchens: the third, called the floor of defence, is pierced with embrasures, and contains two howitzers, mounted on light carriages, which can easily be removed from one part of the circumference to another, and are destined to fire at ricochet over the glacis on the outside, and directly on the ground in rear. The drawbridge gives admission to that floor, whilst the communication between the other parts is established by staircases. On the bomb-proof top of the tower, covered with 3 feet of earth, is a roof called the deck, destined to receive eleven 24-pounders. They are covered by a parapet 33 feet thick towards the exterior, and 10 feet towards the town. Behind this parapet is a circular platform made of three courses of timber: two grooves cut in its circumference receive the trucks of the gun carriages: these peculiar carriages occupy only one yard; and, owing to their great mobility, the fire of the eleven guns can be concentrated upon the same point. Four gunners load and sponge the whole battery whilst standing on the platform, and keep themselves in a little trench reserved between

the parapet and the platform. Six other gunners, standing on the inside, point the guns.

The ammunition, shots, &c., may be carried up the staircases, or through the central cylinder, by a system of pulleys, similar to that of a man of war. The garrison of each tower is estimated at 162 men, 12 of whom are gunners.

An experiment has been made to try the degree of resistance of these towers: a battery of guns, mortars, and congreve rockets, like a ricochet battery, was erected at 300 yards from the front of a tower, and the fire was kept up during five hours, after which it was found that shells had fallen on the roof, broken the carriage, and rendered the battery unserviceable; and even two rockets had entered the superior floor. The defenders of the tower were then sent to repair the mischief, which they did during the night, and next morning they opened fire on the battery in front, and kept it up also five hours. The battery was found much injured. This experiment, however, tells against the tower, because the attack may erect several batteries to concentrate its fire on it, and can replace its losses and gunners, since they are far less exposed than those of the tower, which must be defended by experienced men, who cannot be replaced easily. The circular platform can be disabled by the fall of a single shell, and in so confined a space it becomes very difficult to replace a broken carriage. Another defect is that the vaults are too depressed, and as they rest on the scarp wall, they must give way when the latter falls. One tower being taken, the others cannot resist long, because they are very weak on the interior side. The want of reciprocal flanking may even expose them to a coup-de-main, since there is no loophole or machicoulis to defend their feet, and prevent an enterprising enemy from coming nightly and throwing bags of powder to breach the lower floor.

(427). Towers of a different construction have been erected round Verona, to act as detached forts. They have two floors: the lower, established on the level of the country, contains a loopholed gallery for musketry, projecting 8 feet beyond the wall of the tower, and is surrounded by a small revetted ditch 6 feet deep. The superior floor is intended to form a casemated battery, having a command of 15 feet over the surrounding country. The wall is 5 feet 6 inches thick. On the roof destined to receive 12 guns, the parapet consists of a wall 9 feet thick,

Fig. 825.

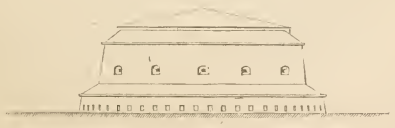


Fig. 826.

through the interior slope of which a circular groove is cut to place the shots in. The gun-carriages are similar to those of Lintz, moving on a little railroad. The central cylinder, 9 feet higher than the whole, serves to establish the communication between the various parts. Most of what has been said of Maximilian towers may be repeated here, and it is the more applicable, since they are not intended to resist field guns, but heavy ones. A shell may disable the platform, whilst the splinters of the parapet and the central cylinder will render the position untenable.

The casemated battery cannot bring more than two guns to bear on the same point, and its wall is exposed to immediate destruction. The inferior gallery may be broken in by the fall of a projectile, thereby exposing the safety of the whole. The small depth of the ditch, and the absence of flank defence, does not seem to be an obstacle sufficiently serious to prevent the enemy from reaching nightly the foot of the tower. These works are evidently a waste of money.

CHAPTER XXVI.

DEFENCE OF FRONTIERS.

(428). Fortification is employed for positions which nature has left without defence, or to increase the difficulties which are offered by mountains, rivers, &c. In the preceding chapters we have examined the different means proposed for constructing a front on a level surface: it is the part of the engineer, when ordered to do so, to make the best of these systems, according to the nature of different localities. But *when he may be ordered to do so* is a question of very high importance, the solution of which is left to statesmen.

No one will ever doubt the necessity of fortifying a dockyard like Portsmouth, or a town like Perpignan, commanding the road from France to Spain across the Pyrenees; but many sound minds will wonder at the immense number of fortresses to be found on the Continent, and erected, to all appearance, *for no purpose.*

(429). Fortifications have been employed to defend frontiers more by *routine* than from imperious necessity. Systems, too, have been proposed for that purpose. The most ancient plan, which bears the name of Vauban, although this engineer often complained that too many fortresses were built, is designed to cover a frontier with a triple line of fortresses, disposed chess fashion at about one day's march from one another, with the view of *detaining the invader as long as possible with small forces, while an army is being organised.*

In this system, routine had the greater part. After the struggle of the middle ages, Europe was seen dividing itself into a limited number of kingdoms; these swallowed up the states of smaller importance, enlarged themselves by the addition of dukedoms and earldoms, and sought to establish themselves on strong bases. Of all fortifications, those which nature supplies are still the best; but every state could not succeed in obtaining for itself such boundaries: even to the present day the coincidence of political with natural divisions is regarded as an impossibility. It happened that to restrain a too warlike nation,—to keep in

check a too powerful country,—the European states imposed on each other frontiers of an irregular shape. The consequence was, that in order to protect the defenceless part of these frontiers and to close the openings, citadels were erected. Political events changed, and with them the frontiers advanced or retreated like the tide of the sea. At every change the same phenomenon took place, and it is for this reason that the surface of European states offers so great a number of fortified towns, scattered about without any apparent combination.

In France, Vauban and his successors improved all these fortresses; and as several lines were found to exist, it was taken for granted that they were built according to the regular system alluded to.

At present, however, invading armies are numerous enough to pass between these lines without having much to fear from their small garrisons, and the examples of Holland in 1794, and of France in 1814, lead us to inquire whether this enormous outlay on artificial defences is not altogether useless.

"We have seen the Romans at Trasimene and Cannæ, Hannibal at Zama, Scipio at Thapsus, Sextus at Munda, Melas at Marengo, Mack at Ulm, Brunswick at Jena, defeated, and unable to rally their forces even amidst their fortresses, and close to their capitals."*

It has been said in defence of this system, and it is still repeated, that an invading army would not dare to venture into a hostile country leaving several fortresses in its rear, because its communications would be cut off. But the invading army is exposed in a limited number of points only to the combined and therefore uncertain attacks of the garrisons, each about 6000 men strong. What may be the strength of the invader? Experience shows that there is no exaggeration in estimating it at 300,000 men. If this army leaves on the frontier a corps of 50,000 men to observe the fortresses, their garrisons could not leave them far without exposing themselves to the attack of a much superior force, and there will be still left 250,000 men to march into the interior of the country. But they would not dare to do so! Why? The defensive army, already inferior, since it is on the defensive, has been diminished, owing to the necessity of placing garrisons in every fortress,—in *every one*, since it is not known which of them the invader intends attacking. For a frontier of 150 miles, requiring about 21 fortresses, the defensive army loses 125,000 men condemned to remain inactive! If in 1814 Napoleon had not scattered garrisons in Dantzic, Homburg, Magdeburg, Wurtzburg, Glogau, &c., but had concentrated these forces on the Rhine, they would undoubtedly have delayed, if not altogether prevented the invasion which followed. The great accumulation of fortified places on a frontier has, besides, the inconvenience of entailing a very heavy expenditure on the State. Valuing

* Montholon, "Mémoires de Napoléon" tome ii, p 206.

the mean cost of a fortified town at £600,000., how many millions will be swallowed up by a frontier 150 miles in length? Look at France, with her 186 fortresses in 1829, and judge what she must have paid for their maintenance alone. Bureau de Pusy said that he could organise an army of one hundred thousand men with the amount which they cost annually.

(430). Modern statesmen have laid aside this system, and proposed new ones. Among the most celebrated we find General Rogniat's method of *Retrenched Camps.** He proposes to leave the frontier open, and to entrust the defence of the country to a numerous army, that shall find support in a series of retrenched camps resting on fortresses, and distributed from the frontier to the central stronghold, in such a manner that the army can always find one within fifty miles. He intends this army to defend the country while other forces are being organized, to check the advance of the enemy by skilful manœuvres, and to drive him to attack the defenders on their prepared ground of the retrenched camps. This system, which has been favourably received, has not yet been tried; and it is therefore difficult to decide upon its merits. It starts, however, from a *true principle*—that of entrusting the defence of a country to the *army*, and not to *mere* fortresses. But the invader can also have recourse to skilful manœuvring, and march directly upon the capital, which, according to General Rogniat, is not fortified. (350).

(431). General Duvivier† proposes to have only one place in a country—but an immense one, 40 miles in diameter!—a *delta*, as he terms it, where all the resources of the State are to be accumulated, so as to preclude even the idea of attacking it, whilst the defensive army struggles on the frontier. Unfortunately, before the realization of such a plan as this can take place, the manners, government, &c., of our times must greatly alter.

It is evident that the siege of a place of that size is next to impossible, because the strength of the garrison is such, that the defenders can make sorties with numbers far superior to the guard of the trenches. The enemy's only chance of success, depends either on a surprise or on a general assault, and it was lately said‡ that history offers a prodigious number of great cities taken by *surprise*, *assault*, or *escalade*, and that most of the capitals of the greatest empires have so fallen. Thus Babylon (538 B.C.), Carthage (146), Syracuse (212), Jerusalem (72 A.D.), Antioch (1097), Constantinople (1453), Rome (1527), Prague (1741), Schweidnitz (1761), Ratisbonne (1809), &c. Experience has certainly proved that the number of defenders of a fortress is not a sufficient guarantee against escalade or surprise; that several enceintes and citadels do not secure it from an attack "de vive force"; that detached forts even crossing their fire do not preclude such an

* "Considerations on the Art of War." † "Essays on the Defence of States." ‡ Prevost Vernois.

attack, especially if they can be escaladed; and that walls of 30 and even 34 feet high, are not free from the danger of escalade. It is therefore prudent to rely chiefly on the efforts of the garrison to compel the enemy to retire, but in order that the defenders may make daily sorties and engage the enemy, it is necessary that the enceinte should present such powerful obstacles, that by their inertia alone and, without the help of defenders, the enemy may be arrested several hours.

(432). The plan which now seems to prevail on the Continent is to fortify the capital, and to have on the frontier a zone of fortresses more or less numerous, from one line to four, as the country is less or more open. The invader is expected to besiege some of these places to secure a base of operations before venturing into a territory, whose army, no longer obliged to cover the capital, can carry on its operations with more vigour. As, however, the enemy, instead of marching on the capital, might plunder the provinces, ransom opulent cities, &c., a few fortresses and intrenched camps are also erected, especially round important towns, to cover magazines, hospitals, recruiting depôts, &c.

The problem of the fortification of a capital is beset with great difficulties, when, like London and Paris, the circumference exceeds thirty miles; it is, therefore, not surprising that engineers should be divided on that question. Some recommend field-works, which cost little, and can be thrown up when the danger of invasion is imminent: others advocate a continuous enceinte, with demi-lunes, &c.: others, again, demand an enceinte, and also a system of detached forts. Paris was fortified in this manner in 1844. Whatever be the method employed, it is generally admitted with Vauban himself, that the fortifications of a capital must answer a different purpose from that of an ordinary fortress.

(433). A system ready-made, like a formula of algebra,* applies to all cases, common sense being sufficient to work it correctly; but in the defence of a country, is a system advisable? Will the invader act exactly in the way foreseen? Will every fortress, line, &c., be called into play? The world of impossibilities daily diminishes, and more especially in war, where almost everything is to be considered as a probability, and provided against accordingly. Alexander, Hannibal, Napoleon, have astonished mankind by the boldness and novelty of their operations; and this may again occur. In comparing the number of sieges with that of battles, it will be seen that the ratio diminishes in proportion as armies have become more moveable, and as the science of war has progressed. From the 10th to the 18th century the number of sieges is greater than that of combats. From 1741 to 1763, it is as 67 to 100; during the French Revolution as 26 to 100, and during the Empire as 16 to 100. Therefore, let us beware of systems, ready-made and answering every purpose, and let *common sense* be our

* "Military and Political Considerations on Fortification."

guide. The lines of Torres Vedras were a better defence for Lisbon than any bastioned or tenaille enceinte, yet they were mere field-works. Let us remember that at present armies are more numerous and more rapid in their movements than formerly, and that a fortress has no influence but on the ground covered by its guns, and that it is only when it is a place situated *there*, and *there* only, *where* the enemy *must* pass, that permanent fortifications are advisable. Let us repeat with d'Arçon,* that—

"At the present day, *professional system* has the effect of spoiling all our ideas, and the poison proves the more dangerous, as it exists without the knowledge of those who are attacked by it, who look upon themselves as only zealously attached to their own art, although they wish by such means to exclude at the same time every other.

"Those who have been advocates of the superiority of the troops of the line have wished for no other troops besides infantry: seafaring people have maintained that ships only are necessary; artillery has pretended to be able to protect everything by means of batteries on the coast. Who can say but that the cavalry also, mounted on hippopotami, may not be disposed for defensive manœuvres?"

Engineers are as equally absurd in imagining that nothing but fortifications are needed to insure the quiet possession of a country. Amid this variety of opinions respecting the means to be employed, nothing appears to have been forgotten except the indispensable necessity of *their being all united* and made to *concur* jointly towards the same end.

(434). It is unnecessary to insist on the truism that the defence of an insular empire depends chiefly on a powerful navy; but it may be said that this force, however great, is not sufficient, because if it were even capable of resisting a coalition between maritime powers, a disastrous storm, or the loss of a single engagement, is an eventuality, which, under the present system of steam navigation, would permit an enemy to appear almost suddenly on its coasts.

What has been said of the continental frontier applies still more forcibly to maritime ones: "it is *there* and *there* only where the enemy *must* come that permanent fortifications are advisable." The enemy advancing to the coast has but one of these two ends in view, either to attempt a descent to cause the greatest possible mischief, or to land and march rapidly on the capital to strike a decisive blow.

The safety of a kingdom is by no means endangered by a piratical descent; but its resources may be diminished by the destruction of its dockyards, and to leave those most important points open would be folly. Every country does

* "Military and Political Considerations on Fortification."

therefore surround its dockyards with fortifications, the nature of which, although modified according to the ground, is yet readily pointed out by the necessity of preventing the enemy from approaching within distance of bombardment. A fortress is surrounded by detached forts, and further defended by floating batteries.

Dockyards are not, however, the only points which require the assistance of fortification. Fleets are made, as well as armies, not to remain inactive, but to threaten and attack the enemy incessantly. Unfortunately they are, however, exposed to many injuries and wants, which often oblige them to seek a momentary shelter in harbours; and as dockyards are far apart, the great mercantile ports and anchorages where they take refuge, should be protected by forts and batteries.

The danger of an advance on the capital is more serious; and it is not surprising that a great number of systems of defence should have been proposed. To organize the defence of coasts, so as to prevent a landing, is as impossible as to arrest an army on open ground by means of fortresses. For such a purpose, forts and batteries would have to be sufficiently close to one another to cross their fire, and sufficiently powerful to struggle advantageously with the ships; and when there are several hundred miles of open coasts, as in England, what an impossible outlay!

But even supposing such a thing possible, how many garrisons should be scattered, which it would be impossible to re-unite in time to offer a serious resistance! This system was, nevertheless, attempted, and General Lewis, in the ninth volume of the Professional Papers, tells us how "fashion, or some prevailing whim, or the accidental success of a work, has regulated the style of fortifications, rather than the peculiar fitness to the ground or object to be gained; hence towers have been multiplied on the coasts of England and Ireland."

To organize the defence with several lines of fortresses between the coast and the capital, is another scheme which bears resemblance to the continental system, whose defects it also possesses.

The capital should be made secure against surprise, famine, and bombardment; but the defence of the territory should be entrusted to active forces—to the army. A good system of signals and of roads parallel to the shore are the best auxiliary means which can be recommended for coast defence. By means of these, several batteries may be concentrated on the point of attack in time to interfere seriously with the landing, whilst moveable corps, stationed at central points, twenty or thirty miles inland, are marched up. This necessarily implies great forces; but a strong army, with a reserve properly organized, and well practised in camps of instruction in time of peace, will always be necessary for the defence of a territory, whether continental or maritime; and Field Fortification,

well understood, will make up for inferiority of numbers in almost every circumstance of war.

(435). Much has been written of late on the influence which the range and the penetration of the new weapons will exercise on Fortification, and it would be trespassing on the limits which we have fixed to this work to follow the writers in all their wandering speculations. We therefore confine ourselves to the statement, that in the alterations rendered necessary, the advantage will chiefly be for the defence.

In the field an army will be too much exposed, even at 600 or 800 yards from the enemy, to remain without cover. The necessity of throwing up parapets, masks, trenches, &c., and of giving them a greater thickness than hitherto, will, it is true, entail more labour; but, on the other hand, as the lines of defence can be made longer, the number of salients, and, therefore, of points of attack will be less, and the enemy, when attacking, will be under fire for a longer time—two great advantages.

In permanent works the lengths of the fronts can be increased, an improvement which modern engineers have recommended both for the sake of economy and defence. The first parallel will have to be opened at a greater distance from the place; the sap especially will begin sooner, and require, in many instances, mantlets and blindages, so much so that the besieger will find it preferable to have recourse to the mine (which is a slow process), to make his advance.

The ricochet of elongated projectiles will not be so accurate. But the besieger being enabled to destroy masonry from a greater distance, it will be necessary to construct works so that the masonry cannot possibly be seen or exposed from a distance. Covers for the artillery, as the Haxo casemates, will also be more frequently constructed.

CHAPTER XXVII.

HISTORY OF FORTIFICATION.

(436). Permanent Fortification undoubtedly preceded Field Fortification, but its antiquity cannot be traced. The first families that settled themselves in a village, or rather in a collection of huts, protected them by palisades, formed of trunks of trees planted close together. At a later period the use of stone became known, and towns were built. However, it was a long time before towns were enclosed. Plunder was the chief object of war, and cities becoming places of comparative safety, people retired to them during hostilities, with their riches. Their population was scanty, and their surface contained a tract of ground sufficient to produce by cultivation the necessary means of subsistence. The capitals of States were the first fortified. History teaches us that Uchoreus surrounded Memphis with parapets and ditches, with the double view of protecting the town against the Nile and the enemy. In Assyria, Semiramis enclosed Babylon with walls; Saba, which Moses attacked, had also walls. So long as the escalade was the only mode of attacking a town, a simple enclosure of walls was sufficient; but soon followed the machines which enabled men to approach these walls under cover, to batter and overturn them. It was observed, that where the inequalities of the ground, or the form of the town, had given an irregular outline to these works, the enemy was sometimes exposed to view. The idea was taken and acted upon, and walls were constructed according to crooked lines, in order to obtain a flank defence; this was afterwards improved by the addition of towers. The science of defence in ancient times does not seem to have made rapid progress: it

FIG. 827.

consisted entirely in giving immense thickness (30 feet) to the walls, piercing loop-holes and machicoulis, giving great relief to the towers, and sometimes forming a double inclosure. This was the citadel or place of refuge for the garrison, when the enemy had succeeded in overthrowing the enceinte. The defence was based chiefly on the courage of the troops, the help of their machines, and the strength of the walls. Citadels were constructed on culminating points of the towns. The use of a ditch in front of an enclosure came later: it was originally destined to receive water.

As long as the battering-ram was the only means of overthrowing the walls, the fortification remained the same; but when, in the middle of the fourteenth century, powder gave to the besiegers a most prodigious power of percussion, the rams were thrown aside, and artillery breached at a distance even the thickest walls. To oppose this new mode of attack, immense remblais of earth were accumulated beyond the wall to increase the power of resistance, and to furnish means for constructing an earthern parapet for the defence of the breach. These remblais, or *Ramparts*, were so called from the Italian, *parare*, to protect; and the syllabic iterative *ren or rem*.

To obtain earth for the rampart, as well as to prevent the artillery from coming too near, the ditches were widened and deepened, and counterscarps of masonry erected.

The towers were abandoned as too small to receive a parapet, and were replaced by *Bulwarks* (from the German *boll*, empty, *werk*, work, probably because their centre had an empty space left by the ramparts), works of the same shape, but much larger. These were connected to the walls by flanks, with the design of overlooking or flanking the foot of the escarp.

Fig. 828.

It was soon found that the circular form could not answer, and it was replaced by two walls or faces directed towards or facing the country. This improvement

Fig. 829.

is attributed to an engineer of Verona, San Micheli (1523), and these modified towers or *Bastions* are still in use.

From the time of San Micheli to this day, permanent fortification has been constantly undergoing great modifications; but the defence has not kept pace with the progress of the attack.

(437). Field Fortification was employed by the Greeks (if not before them), to secure their camps, to strengthen positions in which a battle might be fought and to construct lines of circumvallation and contravallation. The Romans borrowed from Pyrrhus the method of fortifying their camps; and in later times Cæsar employed almost every accessory defence used in modern times, such as palisades, abattis, trous de loup, crow-feet, &c. In the perusal of the history of the middle ages and of modern times, we find numerous instances of the application of the means of defence, but it must be acknowledged that among modern armies, Field Fortification has been undervalued. The improvement in fire arms and artillery will, for the future, compel armies in the field not to despise the powerful assistance which they may receive from a judicious application of its principles.

In passing in review the various methods which have been proposed of fortifying places, we shall arrange their classification into schools; the Italian and Spanish, the German, the Dutch, and the French.

SECTION I.—Italian School.

There is no certainty as to the precise date of the invention of bastions: some historians attribute the invention to John Ziska (1419), the leader of the Hussites in Bohemia; some to the Turkish general Achmed Pacha (1480); some to the Italian Antonio Colonna (1500): others positively state that bastions existed in Italy in 1461; but it is beyond doubt that San Micheli constructed in 1527 two bastions at Verona.

The first bastions were very small, and as the curtains were very long (from 250 to 500 yards), they could not flank one another. Their flanks, about 30 yards long, were perpendicular to the curtain: a third of their length was retired and

Fig. 830.

Fig. 831.

preceded by a low casemated flank; the remaining two-thirds was either traced in straight line or in orillon. The ditch, 30 to 40 yards wide, had a counterscarp parallel to the faces of bastions, or nearly so. It was not till 1540 that a covered way was added. A gallery of mines was frequently constructed along the whole rampart.

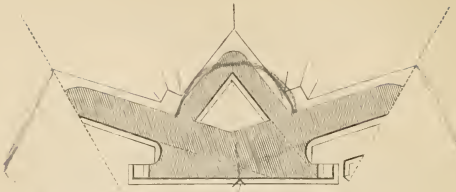
During the 16th century, the Italians improved upon this construction, and spread their principles over Europe, almost every sovereign having Italian engineers in his service. It was chiefly in Spain and the Low Countries, then closely connected with Italy, that these engineers constructed new fortresses, and this is why the Italian method is often called the old Spanish method.

(439). *Italian system.* This was constructed on the interior polygon. The front, from 250 to 300 yards, was divided into six equal parts: the flanks perpendicular to it were equal to $\frac{1}{6}$, and the curtain to $\frac{2}{3}$ of the whole length. The faces of the bastions were obtained by joining the extremities of the flanks to A for the hexagon, to H for the heptagon, and to O for the octagon. The flanks

Fig. 832.

were perpendicular to the curtain because fortresses were not unfrequently attacked on that curtain before the invention of the ravelin; and the faces of the bastions were directed so as to receive flank defence from that curtain. The bastions were generally full and frequently contained cavaliers, the retrenchments and coupures being only constructed during the siege: they had orillons, with retired and double flanks. The ditches were deep and wide, their counterscarp parallel to the faces of bastions and masking part of the flank defence. The ravelin, at first semi-circular, and afterwards triangular, dates from the middle of the 16th century. In the Italian system its faces measured from 60 to 75 yards, and were directed on the angle of the curtain, thereby receiving but little defence from the enceinte. Its ditch was from 18 to 20 yards wide. The covered way was adopted towards 1554, and about 1574 the engineer Cataneo proposed the re-entering places of arms. The palisades were planted on the glacis itself, at about 4 feet beyond the crest; and it was only a century later that the French engineer Naudin placed them on

Fig. 833.



the banquette. The revetments were very high, from 40 to 50 feet, rather

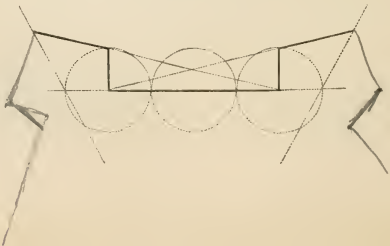
Fig. 834.

massive, and much exposed, since the besieger could see from 15 to 17 feet of the masonry from a distance.

This system was applied by Paciotto D'Urbin in building the citadel of Antwerp in 1567, and by some engineers of the Pope and of the King of Spain, to City-Valette (Malta), in 1566-69. It was also employed in fortifying Turin, Pavia, Milan, Vienna, Raab, Gratz, Ghent, Utrecht, &c.

The construction of the Spanish system was nearly the same, but the lines of defence were directed on the angle of the curtain.

Fig. 835.



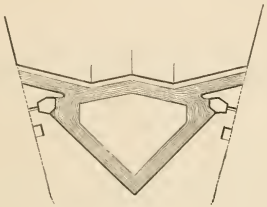
The more noted Italian engineers were:

(440). *San Micheli*, born at Verona, 1484. He was employed by Pope Clement VIII. to restore the fortresses of Parma and Piacenza, and afterwards entered the service of Venice. He constructed the fortifications of Napoli-di-Romania, Candia, and Canea in Crete, Lido at Venice, Verona, &c. He died in 1559.

Nicholas Tartaglia, born at Brescia, 1500, was professor of mathematics at Verona and Vicenza, and died in 1557. He wrote in 1546 (Venice), a work entitled "Questions and Inventions," in which he proposes a system of fortification somewhat similar to the following. The invention of the covered way is attributed to him.

Alghisi-di-Carpi in 1570 published at Venice a work on "Fortification." The curtain forms a tenaille; the main ditch encloses a flat space, and the bastions are small and have orillons and casemated flanks, with a cavalier inside the gorge.

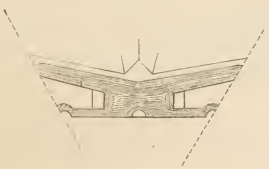
Fig. 836.



Paciotto D'Urbin constructed the citadel of Turin, that (1567) of Antwerp, and several other fortresses in Piedmont and Flanders.

Jacomo Castriotto, Capt., born at Urbino, was an engineer of Pope Julius III. He attached himself to the service of Henry II. of France, and served under Montmoreney, Guise, &c. In his system, the bastions are replaced by round towers, and the enceinte is covered by detached bastions. Vauban borrowed from

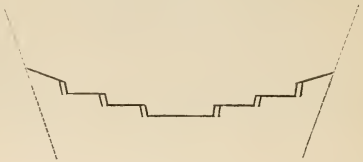
Fig. 837.



him his second and third systems. He recommended demi-revetments and also hollow revetments.

Girolamo Maggi, born at Anghiari, was a lawyer. While judge of the island of Cyprus in 1571, he contributed to the defence of Famagosta, then besieged by the Turks. In 1564 he published at Venice, "Fortification of Cities," on the method of Castriotti, with comments of his own. In the system which he proposes

Fig. 838.



the bastions are small, have double flanks, and the curtain is provided with four double flanks. Vauban borrowed from him the curtain of his third system.

Girolamo Cataneo in 1574 constructed the first place of arms.

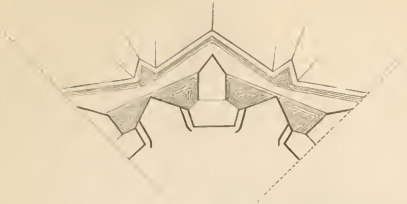
Francesco de Marchi, born at Bologna, was engineer of Pope Paul III., for whom he fortified Piacenza in 1547. He afterwards went to the Low Countries in the service of the King of Spain. His work "Military Architecture," published at Brescia in 1599, contains 161 systems. In them we find the tenaille, ravelin, counterguard, &c., and other outworks and detached works. Subsequent engineers have borrowed from him, and Vauban was at a time accused of having bought up the copies of this work to destroy them, in order to conceal his plagiarism!

Gabriel Busca, who in 1619 published at Milan a work, "Military Architecture," is considered by some as the inventor of the great ravelin; but the German Speckle had already planned it thirty years before, and Busca's system is a mere copy of Speckle's.

Floriani, who, in 1630, published at Venice "Defence and Attack of Fortresses," is the first who employed a double covered way. He is considered by many as the inventor of the tenaille of Vauban.

Donato Rosetti, in 1678, published at Turin "Inverse Fortification," and proposed a system with double flanks not retired, and with a large ravelin with flanks. The shoulder angle of each ravelin is connected by a fausse-braye. The shoulder angles of the bastions and the flanks of ravelin are joined by a wall destined to prevent desertion, and to enable the officers to go the rounds: this

Fig. 839.



wall is destroyed towards the latter part of the siege, to enable the flanks to defend the ditch.

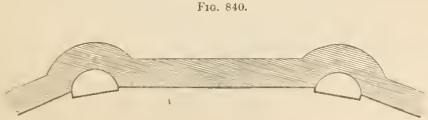
SECTION II.—German School.

Although the German school dates only from 1815, yet Germany has not been without engineers. They chiefly belong to what is termed the "theoretical school," in opposition to the "practical school," of which Vauban is the head. They proposed systems more or less impracticable, and the art did not progress in their hands.

(441). *Durer* (Albert), born at Nuremberg in 1471, was at the same time a painter, sculptor, engraver, and a civil and military engineer. He died in 1528, one year after the publication of a remarkable work, entitled "Instructions for the Fortification of Cities, Castles, and Boroughs." (Nuremberg.) He is the first who has written on this subject since the ancients; and there is no doubt that the Germans owe to him the origin of the ideas on which their modern method is founded.

His fortification consists of a wall, flanked by circular bastions or towers, and a ditch 200 feet wide. The towers are of different tracings. In one project this work

Fig. 840.



is 70 feet high, and commands the enceinte. Artillery is placed on the platform, and a casemate for artillery and musketry allows of giving a grazing fire in the

Fig. 841.

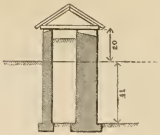
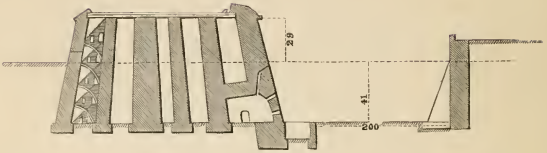
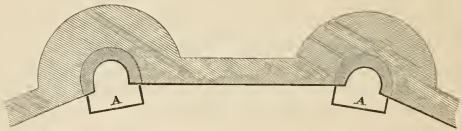


Fig. 842



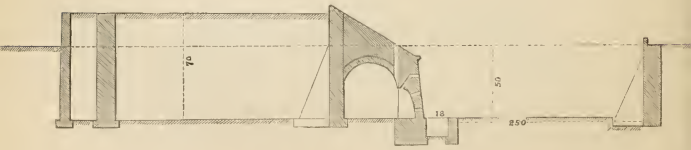
ditch. The wall of the enceinte is double: the top is provided with loopholes and covered with a roof.

Fig. 843.



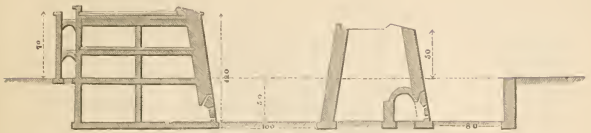
In another project the tower has the same command as the wall, and contains casemates A, A in rear for magazines: the outline of these towers is better calculated to flank the ditch.

Fig. 844.



In his project of a fortress formed of a round tower, Durer has a double enceinte, with caponiers for the defence of the ditch.

Fig. 845.

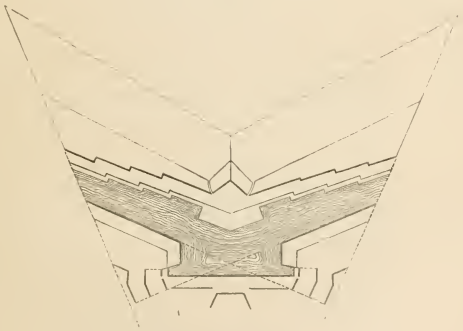


The great dimensions which he adopted, together with the immense cost of the masonry which his project would necessitate, have prevented their application.

(442). *Speckle* (Daniel), born at Strasburg, in 1536, served at first the Emperor of Germany, Maximilian II., as arsenal master; then the Duke of Bavaria, as military architect. He fortified Ingolstadt, Hagueneau, Ulm, Colmar, and Strasburg, and died just after having published his work "Architecture of Fortresses." (Strasburg.) Setting aside the Italian system, he proposes several methods.

In the first, the bastions are large, with orillons and cavaliers, the flanks are

Fig. 846.

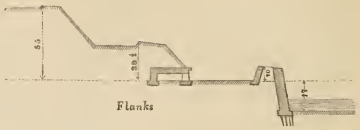


triple, and parts of the middle and upper ones are perpendicular to the lines of defence. There are cavaliers on the curtains. The covered way is en cremaillère,

FIG. 848.

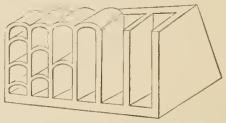
flanked by places of arms. Beyond the glacis there is an advanced ditch. The profiles show the demi-revetment, with

FIG. 847.



its fausse-braye serving as a chemin des rondes. The walls of Speckle have counterforts 5 yards apart, connected at the top by arches, which bear the parapet and render breaching difficult. It is the modern revetment "en décharge." Speckle furthermore

FIG. 849.



proposes the construction of several tiers of arches to resist the fall of the parapet.

In his reinforced method the flanks are perpendicular to the lines of defence, and the ravelin is made very salient. Of the value of Speckle as a military engineer, we may judge by the following principles which he advocated in 1589: the greater the number of sides of a polygon the stronger the fortification, because the works will more readily support each other, therefore the straighter the line of fortification is, the stronger it will prove; the Italian bastions are too small; large bastions are absolutely necessary for a good defence. Cavaliers are needed for each bastion and curtain to impede the progress of the attack, flank the main ditch, and serve as a retrenchment for the garrison; a great part of the flanks should be perpendicular to the lines of defence; casemated galleries are necessary to give a low fire in the ditch, and keep off the miner of the attack; great

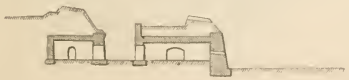
Fig. 850.

ravelins increase the strength of fortification; the covered way is one of the most essential outworks; revetments should not be seen from the country, and the besieger must reach the crest of the glacis in order to breach. All these principles have been duly appreciated by modern engineers.

443). *Dillich.* He published, in 1640, a Latin work, "Peribologia," or Systems of Fortification. (Frankfort.) Improving the Dutch method, he replaces

Fig. 851.

Fig. 852.

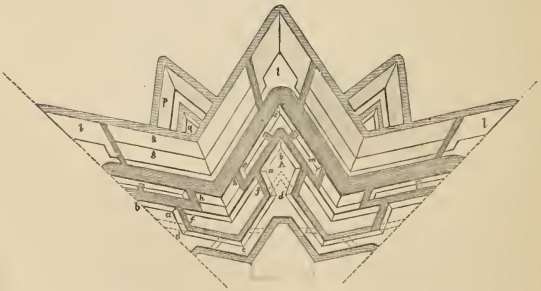


the ravelins before the bastion by counterguards, and directs the counterscarp of the main ditch on the shoulder-angles. His ravelin is also an improvement. His low flanks are casemated on the Italian method. In another system, Dillich adopts the tenaille tracing.

Fig. 853.

(444). *Rimpler,* as military engineer, took part in the defence of Candia, against the Turks (1669). In 1673, he proposed a new system, which he called "Fortification with middle bastions," but gave no drawings. It was only in 1718 that Sturm published a plan of that method. Complaining that his predecessors did not pay sufficient attention to the ground on which the besieger must develop his attack, that the garrison was not well covered, and could not obtain the superiority of fire, he proposed to replace the curtain by a bastion that would flank the collateral works, and be defended by them, to cover the garrison under casemates, and to prepare an interior as well as an exterior defence.

Fig. 854.



In his system, the bastion A is called "bastion of the middle," *a b*, *a b* are the faces, *a d*, *a d* the second flanks, *d c*, *d c* the upper flanks, *f f*, *f f* the middle, and *h h* the lower flanks. The bastions are preceded by fausse-brayes *m m m*, the salient of which forms a bonnet. On the other side of the main ditch, is a double covered way with advanced ditch: the salients are occupied by ravelins *l l*, and the re-entering angles by interior *q q*, and exterior *p p* demilunes. The bastions

Fig. 855.

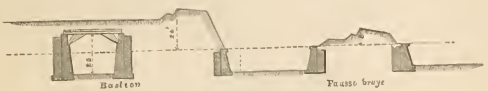


Fig. 856.

Fig. 857.

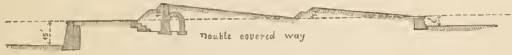


Fig. 858.

are retrenched by means of ditches (punctuated on the plan) over which wooden bridges charged with earth are thrown: the bastions being breached, the bridge is easily destroyed, and the earth above it serves to throw up a parapet. The enceinte is separated from the town by a ditch, and the upper flanks have at their gorge a parapet and defensive casemate for the interior defence.

This system has a great importance not only on account of the excellent ideas it contains, but because the principles of Rimpler have been adopted by Montalembert and the present German engineers. The besieger must carry two ravelins before reaching the counterscarp; then he must attack the fausse-braye, the bastion, its retrenchment, and furthermore drive the defenders from the casemates. The ditches and outworks are powerfully flanked; the retrenchments of the bastions are excellent. On the other hand, the revetments of the escarps are low

and exposed to escalade; the advanced ditch provides the besieger with a lodgment ready made, and the angles of defence are rather obtuse. This fortification is not practicable, on account of the great space it occupies, of the large garrisons it requires, and the immense outlay it would necessitate.

(445). *Griendel d'Ach.*—He published in 1677 "New Military Architecture" (Nuremburg), in which he proposed several methods, the most important of which is a combination of the bastion and tenaille tracings. The enceinte is bastioned and serves as retrenchment: the tenailles are formed of great ravelins traced on the prolongation of the faces of the bastions. The four flanks of the ravelin and

Fig. 859.

its reduit, must be destroyed by the mine when the besieger has breached the ravelin. The ditch of the reduit is defended by a double flank constructed on the face of the bastion. Between the tenailles are ravelins with long flanks. The outlay is great, and the place is much exposed to enfilade; but in 1677 ricochet firing was not yet invented.

(446). *Werthmuller.*—Among several works, his "Theatre of Ancient and Modern Maxims of Fortification" was published in 1691 (Frankfort). He proposed corrections to the system of Pagan (464) and offered a tracing en tenaille. The

Fig. 860.

enceinte has a fausse-braye; and in rear, the buildings are disposed for resistance. The long ravelins are flanked by the enceinte; and their flanks are intended to give a reverse fire in the dead angle of the tenailles. The same remark may be made as before on the ricochet.

(447). *Sattinger.*—A great partisan of Rimpler, advocates the interior defence and the suppression of the curtain. The figure represents one of the systems he offered in 1696, in all of which the ramparts are double.

Fig. 861

(448). *Landsberg*, born in 1670, served as an engineer first in Holland, and after 1733 in Saxony: he died a general-major in 1746, having been present at 20 sieges. He published works entitled "New Method of Fortifying Places," and "Fortification of Everybody." (La Haye, 1712.)

Although he occasionally proposed improvements for the bastion system, he nevertheless attributed the small resistance offered by fortresses in general to the short flanks which this system unavoidably possesses, and insisted upon adopting a maximum flank, therefore having nothing but flanks, and setting aside the bastion form, he adopted the tenaille. Although Griendel d' Ach and Werthmuller, had before him given a similar trace, yet Landsberg was the first who pointed out its properties. He gave several systems, of which the following affords a fair idea of his principles.

It consists of three unrevetted enceintes; the first of tenailles of 60° *a a*, with small redans in the re-entering angles, the second *b b*, of a fausse-braye with bonnets at salient; the third of an envelope *c c*, of 125 to 225 yards faces replacing the covered way. In the main ditch there are casemated redoubts *m m*, for musketry and artillery, as also *r r*, in the ditch that separates the enceinte from the town. The powder magazines Landsberg proposes to place outside, *p p*. It is readily seen that the ramparts are much exposed to enfilade, and yet Lands-

Fig. 862.

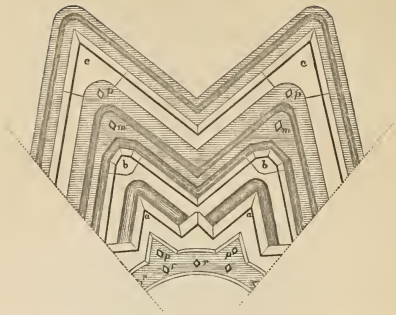
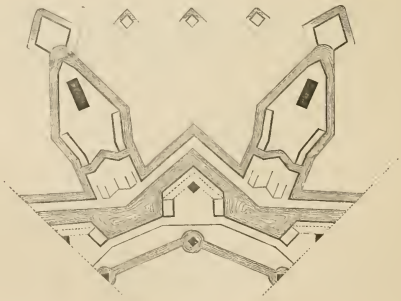


Fig. 863.

Enceinte. *Fausse Braye.* *Main Ditch.* *Envelope.*

berg has no traverse, as he objects to them, because they give cover to the enemy: the absence of a covered way exposes the place to an attack of vive force; and as the relief is small, escalade may be resorted to; there is no provisions made for sorties, and the space left for houses is very limited.

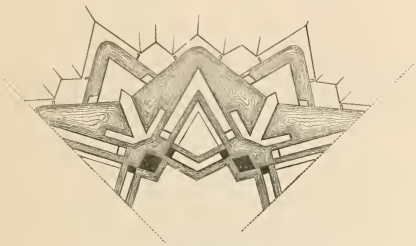
Fig 864.



In another method recommended for a place exclusively military, the first enceinte is bastioned, and the envelope is replaced by salient ravelins with double flanks: some fleches thrown up when the front of attack is known, will form an advanced line; and a retrenchment on Rimpler's principles is prepared in the bastions. Landsberg calculates that the outlay will be less than for Vauban's hexagon, and that a vigorous defence may be expected from a garrison of 20,000 men and 60 guns.

(449). *Voigt.* He published in 1713 a "New System of Fortification" (Jena). He adopts the tenaille with casemated redoubts in the re-entering angles: a

Fig. 865.

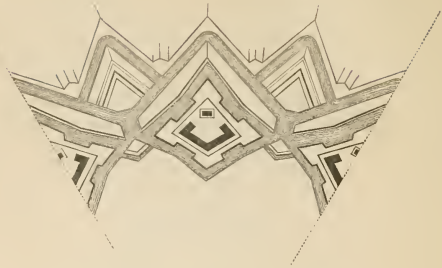


second enceinte is formed of detached counterguards. In capital of the redoubts are ravelins and tenailles, the latter of which served Carnot as models (414). The ditches are made deeper than in Landsberg.

(450). *Sturm* (Leonard Cristophe), born at Altdorf in 1669, was at first professor of mathematics at Wolfenbuttel, then at Frankfort on Oder. He gained celebrity as an architect, and was attached in that capacity to the Duke of Mecklemburg. He died in 1719. He certainly is one of the most productive military authors of Germany. Among his works we may point out his "Comparison between French, Dutch, and German Military Architecture" (Augsburg, 1718).

He also himself proposed several systems of the bastion and tenaille outline. In the method here represented he has imitated Cochorn, and combined both tracings.

Fig. 866.



(451). *D'Harsch.* He published in 1719, "Dissertations on Military Architecture" (Friburg). The enceinte en tenaille consists of a mere wall, forming a parapet, and covered by counterguards, ravelins, and lunettes. Defensive

Fig. 867.

barracks are constructed on the terreplein of the ravelins. Carnot borrowed from him also.

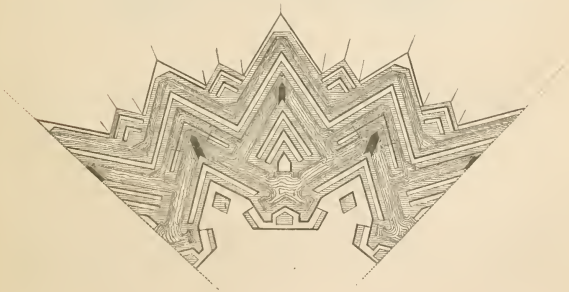
(452). *Herlin*, a major in the corps of the Polish engineers, published, in 1722, "The Complete Works of Rimpley." (Dresden). He proposed an enceinte of detached bastions and ravelins, and divided the town into quarters by double cavaliers erected behind the gorge of the bastions. His ramparts are casemated with a double parapet and a fausse-braye.

Fig. 868.

Fig. 869.

(453). *Glasser.* He published, in 1728, "Ideas on Military Architecture." (Halle). In his reinforced method, which is considered the best, we find a bastioned enceinte, ravelins with reduits, counterguards, envelope and re-entering

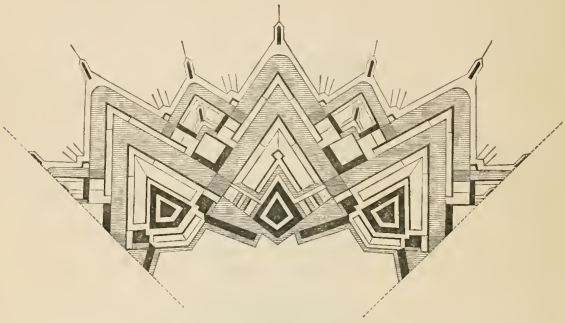
Fig. 870.



places of arms with reduits. The ramparts have a demi-revetment with a chemin des rondes or fausse-braye on the level of the ground. On the capitals of bastions and ravelins are casemated caponiers, which are well covered and powerfully defend the ditches.

(454). *Herbort* was Director of Fortifications in the service of Wurtemberg. In 1734, he published "New Method of Fortification," (Augsburg), in which he proposed two methods. In the first the angles of the polygon are occupied by casemated reduits, surrounded by barracks loopholed for musketry and artillery. These are flanked by two redoubts, and covered by a glacis, before which stands a counterguard. The extremities of these couvre faces form a low flank before the redoubts. Defensive barracks connected by an earthen parapet form a general retrenchment. The ditch is deepened 6 feet before the low flank and the rear of

FIG. 871.



the redoubt, forming an excavation from the counterscarp, of which a grazing fire may sweep the ditch. On the middle of each front are similar casemates with glacis, counterguards, and extra flanks. An envelope of counterguards flanked by lunettes, which have also their glacis, casemates, extra flanks, &c., surrounds the whole. This ingenious system has many defects: the outlay is enormous, the unrevetted parapets and the flanks rising in tiers would expose it to an attack of vive force: it would also suffer much from ricochet. The bastion tracing has a great resemblance to this.

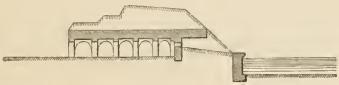
(455). *Augustus II.*, King of Poland (1737), proposed several systems, most of which are so complicated as to be impracticable. The following was intended

for Wittemberg. The gorge of the tenailles is occupied by two parallel defensive barracks, and by casemated redoubts.

Fig. 872.

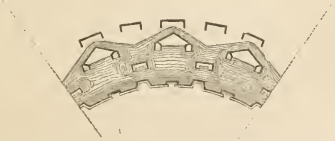
Among the several kinds of casemates which he traced, we notice the following, which bears resemblance to the plan of Haxo.

Fig. 873.



(456). *Pirscher* published in 1771, "A New and Easy Method of Fortification" (Berlin). His enceinte is circular, and the ditch is occupied by two lines of works

Fig. 874.



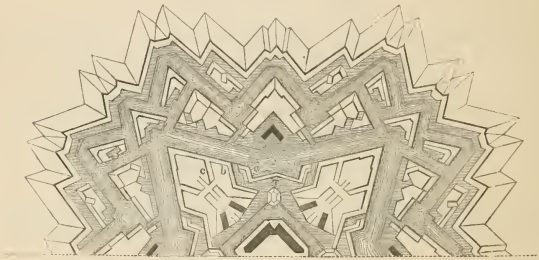
mutually flanking each other. The covered way and glacis are replaced by advanced works.

(457). *Virgin* was a Swedish general officer. He published, in 1781, "Defence

of Fortresses in Equilibrium with the Attack." (Stockholm). This is a remarkable work, and contains the following objections against Vauban's systems, that the breaches cannot be vigorously resisted, that the interior defence is not provided for, that the ravelin is too obliquely flanked, that the fire of the enceinte is too high to sweep the ditch, that the counterguards are not properly flanked by the ravelin, that the covered way is not calculated for sorties, &c.; and he proposes several systems more or less complicated, but he does not give profiles. This plan represents his fortification on a square: he is an advocate for surrounding cities with walls only, and for the construction of small fortresses or citadels exclusively military.

The enceinte is bastioned with a triple flank: the low flank *a*, the middle *b*, and the upper one *c*, with terreplein respectively 2, 14, and 24 feet above the ground, and parapets 6 feet high. They are at such a distance apart as not to interfere with the service of artillery, and they not only defend the ditch and overlook the enemy's batteries, but also can direct reverse fire on the lodgment of

FIG. 875.



the bastion of attack, provided its upper flanks have been levelled in time. The bastions are protected against ricochet by a bonnet at the salient as well as by the flanks themselves. The curtain forms a re-entering angle, and serves with the tenaille to give a well directed fire on the outworks. Barracks may be erected at the gorge.

The interior defence is admirably organized by means of bastioned towers T, and a donjon A, both of a command equal to that of the bonnets. The towers are casemated and covered with a platform which can receive artillery: they are separated from the donjon by a wet ditch. This donjon consists of a double vault, divided into two stories and surmounted by a platform from which the

bastion can be swept. On the outside, the casemates are mounted with guns, destined to fire on the lodgment on the bastion, and to defend the passage of the ditch; on the inside the first story is loopholed for musketry, and the second receives mortars which can fire over the opposite side of the donjon, an invention which Carnot appropriated to himself. As each face of the donjon can direct 24 guns on the terreplein of the bastion, there will be, including 32 guns from the towers, 56 which the enemy cannot see until he arrives at the salient of the bastion. If we add 10 guns from the upper flanks of the collateral salients, and 20 more for which room can easily be found on the terreplein of the curtains not attacked, there will be 86 guns to receive the besieger on the breach, even without the mortars!

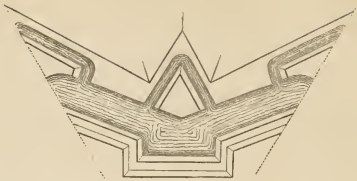
As for the outworks, they consist of ravelins, counterguards, tenaillons, and covered way; of the ravelin with a bonnet at salient and a loopholed gallery under its rampart, flanking powerfully the counterguards with its retired flanks; the counterguards giving a good fire on the capital of the bastions; the tenaillons acting as couvre face to the counterguards; and of the covered way with a double terreplein receiving additional strength from its lunettes. This covered way, although without traverse, is not much exposed to ricochet, and can offer a serious resistance: the ravelin is too small, and the enemy can simultaneously crown its covered way and that of the counterguards.

SECTION III.—Dutch School.

(458). The Dutch school took its rise in the middle of the sixteenth century, and sprang from the struggles of the war of independence. The want of time and money, and the aqueous nature of the soil, led the engineers to adopt fortifications almost entirely made of earth and wood. In this school masonry is rarely employed: the command is small, the number of outworks considerable, especially of hornworks and crownworks, and the defensive character of this fortification is strongly marked. The formulæ of the tracings are generally complicated by geometrical constructions. The chief engineers were:—

(459). *Freytag*, who published "New and Enlarged Military Architecture." 1630 (Leyden). In his method he fixes the maximum of the angles of bastions at 90°. The flanks are perpendicular to the curtain, and the whole enceinte is surrounded by a fausse-braye on a level with the ground. The salients of bastions are covered by lunettes, and the curtains by ravelins. The escarps have no revetment. The chief defence of this fortification rests on the wet ditches, which, however, would fail in frosty weather. The ravelins are too small to cover

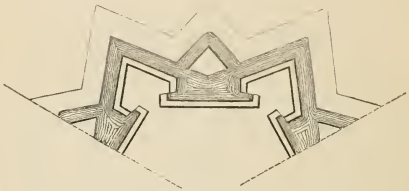
Fig. 876.



even the curtain, and the lunettes, when taken, afford an advantageous lodgment for the enemy.

Marolais (Samuel), who in 1627 published "Military Architecture" (Amsterdam), and also adopted the fausse-braye: the flanks were retired and casemated.

Fig. 877.



Volker (1666) proposed a larger ravelin, triple flanks and the fausse-braye.

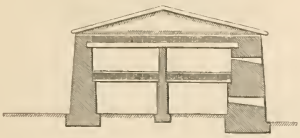
Melder (1670) gave a tracing that differs from that of Freytag, by the absence of ravelins on the salients of bastions.

Russenstein (1670) followed Pagan (464) with this difference, that his bastions are simple. He gave a revetment to the escarps.

Fig. 878.

Scheiter (1672) published "The Newest Military Practice" (Brunswick): he borrows from Castriotto the detached bastions, gives to them a fausse-braye, as well as to the enceinte, and surrounds his place by a double covered way. Among his proposals, we may notice his counterguards, which consist of two walls 18 feet

Fig. 879.



thick, 50 feet apart, with a roof of timber and earth; the interior space is divided by a floor into two stories, affording room for two tiers of guns.

Neubauer (1671) gave to the re-entering places of arms a reduit that was imitated by Cormontaingne, and proposed six fold flanks.

Heideman (1673) imitated Speckles.

Heer (1689), with his twelve systems, came next, and after him Cœhorn, who is called the head of the modern Dutch school, as Freytag and Marolais were called the head of the old.

(460). *Cœhorn* (Minno Baron) was born at Leeuwarden in 1641. He served with distinction in the wars of 1672-76, and rose to the rank of Lieutenant-General. He defended Namur against Vauban in 1672, and conducted several sieges during the wars of the league of Augsburg, and of the Spanish succession. He was also an excellent general officer, and forced the French lines between the Scheldt and the sea in 1703. He died in 1704. His principal work is "New Fortification." (Leeuwarden, 1702). His method of attack was the very opposite of that of his contemporary and rival Vauban; whilst the French engineer advanced surely and slowly, sparing life and intrenching every step, Cœhorn sacrificed everything to time, and trusted to an overwhelming fire of artillery and audacious assaults. It is thus that at Bonn, in 1703, besides a large park of heavy ordnance, he employed 500 small mortars to throw grenades.

We may here say a few words on the method he employed in fortifying a height that commands Gröninguen. It is entirely different from his three systems (fig. 880), and consists of independent works so combined, that the loss of one of them does not entail the fall of the rest. On the outside the works present themselves as tenailles, whose wet ditches are flanked by double traverses, which are

Fig. 880.

themselves insulated by the ditch. On the inside, the gorge of each tenaille is closed by a bastioned front with a weak parapet, so as to be easily destroyed from the place, should the enemy become master of a tenaille. The escarps and counterscarps are revetted, and a covered way surrounds the whole.

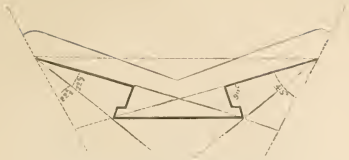
SECTION IV.—French School.

(461). The first engineer who began to modify the fortifications in France was a Spaniard, *Peter de Navarre*. He had served in the Spanish army against the Moors and against the French, had been made prisoner by the latter at the battle of Ravenna, 1512, and afterwards entered their service. He was the first to introduce mines and countermines. He breached the castles of Nuovo and Del Ovo at Naples, in 1503, by mining. Contemporary with Peter were the two distinguished engineers *Micadel* and *La Fontaine*, but none of them left any work. The Italian system was adopted, and Catherine of Medicis invited several Italian engineers into the French service; among them, *Adam de Crapone, Campi, Bellarmato, Bephano, Castriotto d'Urbin*, &c., by whom Landricies, Philippeville, Thionville, Metz, &c., were fortified.

Beroil de la Treille is the first French author on Fortification, but he followed the Italian principles: his work, "Manière de fortifier les Villes et Chateaux," was published in 1557 at Lyons.

(462). *Errard de Bar-le-Duc* is considered as the head of the French school. He published in 1594 "Fortification démontre et réduite en Art;" he constructed the citadels of Amiens and Verdun, and also fortified Montauban, Sedan, &c.; he belonged to the corps of military engineers formed by Sully in 1602. He is the first who fixed, at 60°, the minimum of the salient angles, who adopted 290 yards as the maximum of the line of defence, and who fortified on the exterior polygon. His system, however, is inferior to the Italian. He had for a rival

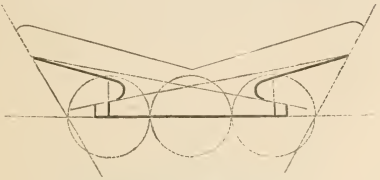
Fig. 881.



Claude Chatillon, who, for the first time, employed the soldiers instead of hired labourers, to work in the trenches.

(463). *Antoine Deville* (Le Chevalier), born at Toulouse, 1596, died a general 1657, published in 1628 (Lyon) "Les Fortifications du Chevalier Antoine Deville;" and in 1639, "De la Charge des Gouverneurs des Places," a work highly commended by Carnot. He is the first who wrote on mines. He fortified Calais, Montreuil, &c.

Fig. 882.



His system is a mere modification of the Italian front.

(464). *Pagan* (Comte de, Blaise François), born at Avignon, 1604, entered the army when twelve years old, served with distinction, and became general in 1642. Although having lost his sight, he devoted himself to the study of Fortification and Mathematics till his death in 1665. Besides several works on Astronomy, he published (1645) "Les Fortifications de M. le Comte de Pagan," Paris.

Pagan greatly improved the art, and paved the way for Vauban.

He adopts three kinds of Fortification, the great, the mean, and the small; in the first the front = 390 yards; in the second, 350 yards; and in the third, 312 yards. He was the first to employ the perpendicular, which he equals to 58 yards, to draw the line of defence. The faces of the bastion = $\frac{1}{10}$ of the front. The flanks are perpendicular to the lines of defence. The ditch is 30 yards

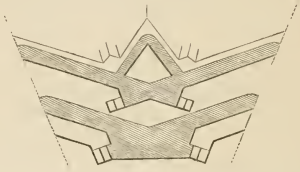
wide at salient, and its countersearp is directed on the shoulder angle of the bastion. Inside each bastion he constructs an interior retrenchment, its magistral

Fig. 883.

being parallel, and 32 yards from the enceinte. The flank is triple; the first is retired and on a level with the ground, the third is on a level with the inner bastion, the second has an intermediary command. The ravelin has a 90 yards' face, and occasionally receives a reduit. A counterguard sometimes covers the bastions.

In another method, called "re-inforced," the enceinte is preceded by a continuous envelope.

Fig. 884.



Despite the many advantages which the Fortification of Pagan possesses over that of his predecessors, it contains several defects, among which we may mention the possibility of breaching the curtain from the re-entering place of arms, thereby turning the interior bastion.

The triple flanks are also defective, the defenders being too much exposed to the splinters of the upper scarps.

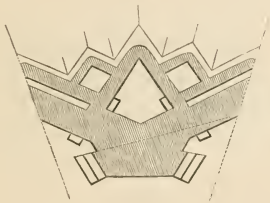
(465). *Vauban* (Sebastien le Prêtre de), born at Saint Leger, 1633, entered the service in 1650, became general in 1688, and died Marechal de France, 1707.

He is the best engineer that France boasts of. He never wrote on his method. He fortified thirty-three places, and improved upwards of 300, and his successors, in comparing his works, have, for the sake of simplicity, classified them into three systems. He conducted fifty-three sieges, and never defended a single fortress; and so greatly did he improve the means of attack, that the defence has ever since been unequal to it. In 1673, at the siege of Maestricht he invented the parallels; in 1683, at the siege of Luxemburg the trench cavaliers; in 1697, at the siege of Ath, the ricochet fire. He left twelve volumes manuscript (a few only have been published) "Mes oisivetés." The volumes 8 and 9 treat of the Attack and Defence of fortresses. Among the fortresses which he constructed we may name Dunkirk, the citadels of Lille, Ath, and Charleroi; Maubeuge, Saarlouis, Phalsburg, Longwy, the citadel of Strasburg, Toul, &c., &c.

(466). *Allain-Manesson Mallet* (1630-1706), was born at Paris. He served as military engineer in the Portuguese army under Marechal Schomberg. In 1671 he published "Travaux de Mars" or "new fortification," the first valuable work written on the subject. In 1667, he fortified the castles of Aronche and Fereire.

(467). *Blondel*, François (1617-1686), was born at Ribemont. After having travelled in Germany, Italy, &c., and performed diplomatic missions in Egypt and Turkey, he became famous as an architect. In 1683, he published (Paris), "Nouvelle manière de fortifier les Places," and Lewis XIV. rewarded him with the honorary title of Marechal de Camp.

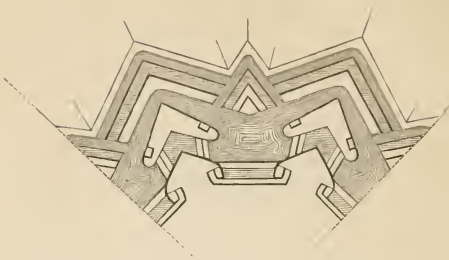
Fig 885.



In his system, the bastions are large and acute: their flanks are long and triple. The bastions are covered by counterguards, whose ditches, like those of the ravelins, are defended by low batteries. Small ravelins are substituted for the reduit of the re-entering place of arms. It is weak in outline, and yet costly in masonry.

(468). *Bernard.*—In 1689, he published (Amsterdam), "La nouvelle manière de fortifier les Places." He proposes a double enceinte covered by counterguards

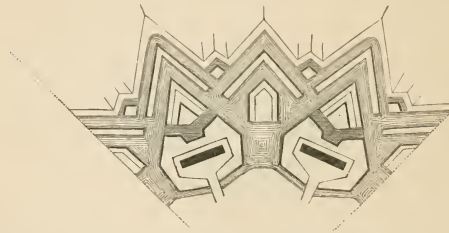
Fig. 886.



and ravelins having high and low faces. The outer bastions can be isolated, after the enemy has opened a breach, by blowing up the flanks. He gave two other methods, which are also based upon good principles.

(469). *Saint Remy.*—The enceinte is composed of isolated forts well covered

Fig. 887.



by ravelins, counterguards and lunettes. Each fort contains a barrack for the garrison. The capital defect of this system is, that the loss of one fort deprives the collateral ones of flanking defence on half their perimeter.

(470). *Rosard*, at first in the French engineers, became Director of Fortifications in Bavaria. In 1731, he published (Nuremberg), "Nouvelle Fortification Française." In his system, which would be good if the enceinte were not exposed

Fig. 888.

to be breached from the covered way of the ravelin, the bastions and ravelins are retrenched: the flanks are formed of good casemates, which secure the defence of

Fig. 889.

the main ditch. The tenaillons and counterguards, however, do not sufficiently cover the bastion and ravelin; the first covered way has retrenched places of arms: the second is defended by lunettes, which communicate with the place by means of galleries.

(471). *Cormontaingne* is supposed to have been born in 1692. In 1716, he entered the corps of engineers, and soon acquired an European celebrity by numerous publications on Fortification, in which he corrected the methods of Vauban. In 1728, he constructed at Metz the crown-work of Fort Moselle, and in 1733 that of Bellecroix, in which are found most of the improvements he proposed. In 1734, he distinguished himself at the sieges of Traerbach and Philipsburg; in 1738, he constructed the crown of Yntz at Thionville; in 1744, was at the sieges of Tournai, Fribourg, Menin, Ypres, &c. He died in 1752 a general. He left several memoirs, which were published long after his death, under the title "Memorial pour la fortification, l'attaque et la defence des Places," (Paris, 1809.) A more complete edition was published in 1835.

(472). *Belidor*, Bernard Forest de, (1697-1761,) was born in Catalonia of French parents. He served in the corps of engineers during several campaigns,

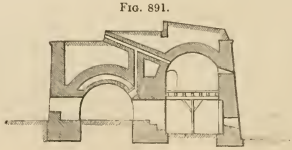
and then became professor at the school of artillery at La Fére, and general inspector of sappers. He invented the globes of compression, which were tried for the first time at Bizi, in 1753. He is the author of several works. Among them we may mention "La Science des Ingénieurs, 1749; Architecture hydraulique, 1750." He proposed several systems, but only gave drawings. The following resembles Rosard's method, but is not so good: a first enceinte consists of small bastions; a second of large bastions with retrenchments; a third of outworks,

Fig. 890.

viz.: a ravelin defended by a redoubt which covers the retired flanks, and is preceded by a casemated lunette, tenaillons with retired and low casemated flanks, &c. The redoubts of re-entering places of arms, are formed of loop-holed walls. The glacis is further defended by lunettes. The profusion of masonry renders this system impracticable; and the great number of outworks would necessitate a very strong garrison. Its merits are those of obliging the besieger to employ a numerous artillery to ricochet a front, and to pass successively through four periods of breaching batteries.

(473). *Rottberg.*—In 1744, he published "L'ingénieur moderne" (La Haye). Criticising Vauban without moderation, and even without reserve, he borrows from Rosetti, Speckle, Rimpler, Cœhorn and Landsberg. His enceinte consists

Fig. 891.



of a belt of isolated forts and cavaliers, the rampart of which is casemated. A casemated wall, situated in the ditch at the salient of the bastion adjoining the cavalier, serves to flank that work. The exterior fronts of the forts are covered by a couvre-face formed of a double covered way; the inner one serving as reduit is secured against enfilade by a casemated bonnet. The ditch, which is partially wet, receives its defence from the cavalier and the flanks of the bastions. The

Fig. 892.

ravelin and its reduit are casemated; but the casemates of the gorge of the reduit are opened to the rear to be exposed to the view of the place, whilst the ditch before the faces is defended by a reverse gallery constructed at the salient of the ravelin. On the capitals of the forts are casemated fleches with a covered way capable of maintaining a protracted defence. The loss of one fort does not entail the fall of the others; and their small garrisons of 500 men and 100 cavalry well covered, would offer a good resistance; but the armament necessitates a very numerous artillery.

(474). *Robillard.* His system is called "system of demolition." The enceinte resembles that of Vauban: the outworks consist of ravelins, counterguards, and

Fig. 893.

fleches. The terrepleins of all these works are intersected by ditches, which are covered either by masonry or by wooden frames and earth, so that when the besieger has breached a work, the defenders obtain at once a retrenchment by removing that masonry or wood by the mine.

(475). *Saxe* (Maurice, Comte de), born at Dresden in 1696, was the natural son of Augustus II., King of Poland. Entering the service when twelve years old, he served at first against France, and was present at the battle of Malplaquet, then he fought under Prince Eugene against the Turks, and in 1720 entered the French army, as a general. We find him Marechal in 1743. In the war of 1744-47, he gained the victories of Fontenoy, Raucoux, and Lawfeld. He died in 1750. Finding fault with the great outlay on a place constructed on Vauban's principles, he proposes a fortress for 10,000 men, in which wood is substituted for masonry. The body of the place consists of an earthen cavalier; inside which,

FIG. 894.

wooden barracks are constructed; it is surrounded by an enceinte of small bastions; a third enceinte is formed by large ravelins, the rampart of which is pierced with long embrasures for the defence of the main ditch. A fourth enceinte

FIG. 895.

of narrow counterguards is constructed with wood and earth, and it has also embrasures through which guns mounted on rafts can be fired.

As the salients of the counterguards are organized into casemates, open at the

FIG. 896.

rear, the defenders can easily destroy them by artillery, and thereby prevent the enemy from forming a lodgment. A lunette, with retired flanks, defends the ditch, and a covered way surrounds the whole. At about 3000 paces from the centre of the fortress, a continuous line of redans and curtains forms an advanced enceinte, the redans, 36 in number, contain solid towers of masonry 25 feet high, several of which the besieger must take before he can open the trench. Marechal of Saxe believes that the construction of such a fortress would only require two months, but the immense quantity of wood which it requires is not easily procured. Besides, wood buried under earth decays rapidly, and consequently his place could not last long.

(476). *Filey* was a General in the French Engineers. He calls his system

Filey was a

FIG. 897.

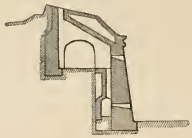
"Fortifications de Mezalectre," because the curtain is replaced by a bastion or mezalectre, whose flanks defend the collateral works. There are cavaliers on the curtains, retrenchments in the bastions, tenailles between the bastions and mezalectre, ravelins, counterguards, and covered way. The great defect of this system is, that the enemy can attack the mezalectre instead of the bastions.

(477). *Lachiche*, also an officer of the Engineers, gives a front similar to that of Cormontaingne, except that the perpendicular $= \frac{1}{7}$ of the front, and that the salient places of arms have fleches for reduits. In order to remedy the effects of ricochet and vertical fires, the artillery is placed under casemates of a new model.

Fig. 898.

The bastions, reduit of ravelin, salient of ravelin, and the fleche have the profile;

Fig. 899.



the curtain, the reduits of re-entering place of arms, and the faces of ravelin have casemates open at the rear. The lower gallery serves for musketry, and

Fig. 900.

facilitates the ventilation of the upper casemates. The glacis has a sufficient command to mask all the masonry.

It may readily be seen that the fleches protect the covered way against enfilade, and that there is very little room left for the besieger to construct his counter-batteries against the flanks; but the outlay on masonry is enormous, and the ventilation of the casemates is not sufficient. He is the precursor of Montalembert.

(478). *Falois*, a major in the Saxon engineers, published in 1768 "L'école de Fortification" (Dresden). He proposes to reduce the strength of the garrison and to increase the armament of artillery. His front consists of two enceintes of equal

command, so that the inner one is well covered. The bastions contain cavaliers

Fig. 901.

which may readily be transformed into retrenchments. The second enceinte consists of counterguards and ravelins connected by batardeaux. A low battery forms the reduit of ravelin. The ravelin, its reduit, and the counterguard are casemated for artillery as in the accompanying profile, the cavalier and curtain as

Fig. 902.

in the profile, both dispositions being good. The covered way is replaced by a

Fig. 903.

system of cremailleres, which possess the great defect of furnishing the besieger with a parallel ready made.

(479). *Rhana*, a professor of mathematics, offered in 1769 a system, whose singular features point out the absurdity of abstract calculations applied to our

Fig. 904.

science. The bow and arrow, the sword, shield, and lance, are combined in this outline.

(480). *Montalembert* (Marc, Rene, Marquis de), born in 1714 at Angoulême, died a general at Paris in 1799. He entered the cavalry in 1731, served with distinction in the seven years' war, and was present at nine sieges. Governor of the isle of Oleron, 1761, he constructed an intrenched camp round the citadel. He spent the rest of his life in the preparation of his celebrated work "Fortification Perpendiculaire" (1766-1796), in eleven volumes. His ideas were not accepted by the French engineers, but they found favour in Germany; and in fact he is the head of the modern German school.

(481). *Cugnot* (Nicolas Joseph), born at Void, in 1725, died in 1804. He served early in Germany as an engineer, entered the service of Prince Charles in the Low Countries, and came to Paris in 1763 to give lessons in military arts. He invented a new musket, a steam waggon, &c. Among other works he published in 1778, "Théorie de la Fortification" (Paris). He adopts a circular tracing

Fig. 905

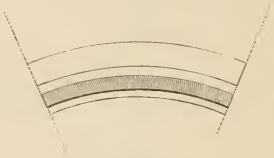


Fig. 906.

and dispenses with outworks. The revetment of the escarp contains a loop-holed gallery with machicoulis for the defence of the ditch and counterscarp.

(482). *Trincano* (Didier Gregoire), born at Vaux, 1719, died in 1792. He was professor of mathematics, but served as engineer at the sieges of Friburg in 1744, and of Berg-op-Zoom in 1747. He was employed by the Dey of Tunis to

fortify Kairovan. In 1755 he published "Discours sur les Fortifications," and in 1778 "Elements de Fortifications" (Besançon). His son, who died in 1785, was also a good engineer.

His bastions are large and retrenched at the gorge: the flanks are triple; the outer is casemated and separated from the bastion, the inner forms a cavalier, and is preceded in the capital by a reduit with covered way. The enceinte is well covered by counterguards and ravelins, the latter having a circular battery at their salient to fire on the approaches. The salient places of arms have the form of bastions. The traverses of the covered way consist of sap-rollers supported by

Fig. 907.

trucks; and before abandoning this outwork the defenders can overthrow them into the ditch so as to leave no cover. The palisades are fixed to a ground sill, and thus can be lowered or raised at pleasure: when their points rest on the crest of the glacis the defenders can use them as ladders to make a sortie.

(483). *Reveroni*, an officer in the engineers, proposed in 1794 a peculiar system. The enceinte consists of a bastion front casemated on a peculiar principle: the guns are placed on a "basculc," and are only exposed when actually firing. Their recoil lowers them and closes the embrasure with an iron trap.

Fig. 908.

Fig. 909.

In rear is an earthen retrenchment: in front earthen counterguards are defended by the casemated flanks of a ravelin. The reduit of this work is also casemated. However ingenious, this system of casemate is not practicable.

(484). *Bousmard* (Henri Jean Baptiste de), born in 1749 at St. Mihiel, entered the corps of engineers in 1768, and emigrated in 1792. While in retirement at Wiesbaden, from 1792 to 1796, he wrote his celebrated work, "Essai General de Fortification." This work was published at Berlin in 1797, and dedicated to the King of Prussia. Compelled by poverty to take service, he accepted the grade of major in the Prussian engineers, and served his new king faithfully. He died in 1807 in defending Dantzig.

(485). *Chasseloup-Laubat* (François, Marquis de), born at St. Sornin in 1754, was colonel in the engineers in 1789. He conducted the siege of Maestricht in 1794, and that of Mayence in 1795. In the campaign of Italy, 1796, during which he was raised to the rank of general, he took Peschiera, Mantua, Alessandria, and was employed to fortify them. It was in these places that he applied his system. In 1807 he carried the celebrated sieges of Dantzig and Stralsund. It was he who commanded the engineers in the campaign of Russia. He died in 1833. In 1805 he published "Extraits de Memoires sur quelques parties de l'Artillerie et des Fortifications."

(486). *Carnot* (Lazare-Nicolas, Marguerite), born in 1753 at Nolay, was a captain in the engineers in 1789; his republican principles opened him the door of the Legislative Assembly and of the Convention. In 1793 he contributed to the victory of Wattignies. Elected member of the Committee of Public Safety, he devoted himself exclusively to military affairs, and prepared the schemes of campaign for the republican armies. Secretary at War in 1795, he was soon expelled by Barras, and obliged from 1797 to 1799 to take refuge in Germany. Recalled by Bonaparte, he became Secretary at War from 1800 to 1802, when faithful to his

political principles, he retired into private life, having strongly opposed the creation of the Empire. In 1814 he accepted service, and was entrusted with the defence of Antwerp. At his return from Elba Napoleon made him Minister; banished at the Restoration, he retired to Cernay, then to Warsaw, and lastly to Madgeburg, where he died in 1823. He left several works: the most celebrated is "De la Defense des Places Fortes," 1810, which he wrote at the request of Napoleon.

(487). *Noizet*, a general in the corps of Engineers, is now living. While Professor of Fortification at the school of Metz (French Woolwich) he corrected the system of Cormontaingne, and offered a tracing which has been adopted in France as "*the* modern system." In 1860, he published an excellent work, "Principes de Fortification." (Paris).

(488). *Dufour*, a general in the service of Switzerland, is now living. He served at first as an officer in the French corps of Engineers. In 1847, he commanded the federal forces. He has written several works, among them "De la Fortification permanente," (Geneva, 1822), in which he proposes a new system, which is preferred by many to that of Noizet.

(489). *Choumara*, a colonel in the corps of Engineers, is now living. He established his reputation in 1827 by the publication of his "Mémoires sur la Fortification," whilst yet a captain. Meeting with jealousy at the hands of his superiors, he felt so discouraged that twice he retired from the service. He has rendered great services to his country: and of his inventions, the barrack kitchens (fourneaux économiques) merit special notice, for these kitchens save upwards of fifty per cent. of the fuel hitherto consumed by the army.

(490). *Haxo* (Francois Nicolas Bénoit, Baron) born at Lunéville in 1774, died at Paris in 1838. Served under Chasseloup in Italy, and afterwards at the sieges of Saragossa, Lerida, and at the battle of Wagram. He conducted the sieges of Mequinenza and Tarragona, made the campaign of 1812, as aide-de-camp to Napoleon, became lieutenant-general in 1813, and fought at Waterloo. Under the Restoration, he was appointed President of the Committee of Fortification, and fortified Belfort, Sedan, Grenoble, and l'Ecluse. Under Louis Philippe, he conducted the siege of Antwerp. As we have said, Haxo did not publish any thing, and there is no fortress built exclusively on his system. His casemates are to be found, however, at Grenoble, and at Lyons in the forts Loyasse and Sainte Foy.

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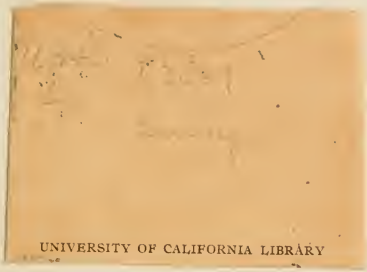
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